

Welcome to

NASA Applied Remote Sensing Training Program (ARSET)

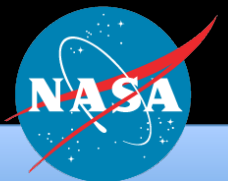
Webinar Series

Introduction to Remote Sensing of Snow Properties

Course Dates: Every Tuesday, January 16 – 6 February 2013

ARSET
Applied **R**emote **SE**nsing **T**raining

A project of NASA Applied Sciences



NASA Earth Science Applied Sciences Program

Applications to Decision Making: Eight Thematic Areas



Agricultural
Efficiency



Air Quality



Climate



Disaster
Management



Ecological
Forecasting



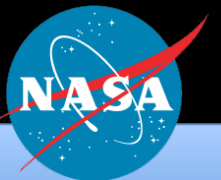
Public Health



Water
Resources

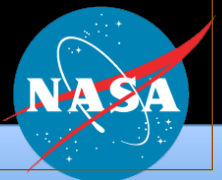


Weather
(Aviation)



Who Can Benefit from ARSET Courses?

- **Public Sector:** Local, state, federal, international regulatory agencies, project managers, health and disaster management agencies, World Bank, United Nations
- **Private Sector:** industry, NGOs, consultants, and other organizations involved in capacity building
- **Scientists/Technical Experts:** Meteorologists, Modelers, Hydrologists, Agriculture, Health and Disaster Researchers



Applied Remote Sensing Training (ARSET)

Professional courses on remote sensing applications

31 courses to date

Water Resources and Disaster Management

<http://water.gsfc.nasa.gov>

Air Quality (since 2008)

<http://airquality.gsfc.nasa.gov>

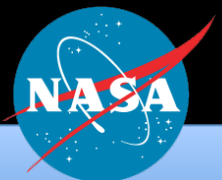
Online courses:

- Required for hands-on courses
- For managers and technical staff

Hands-on courses:

- More technical
- Basic or advanced

ARSET works directly with agencies
in the public and private sectors



ARSET Water Resource Management

<http://water.gsfc.nasa.gov/>

ARSET – Water Resources Management

water.gsfc.nasa.gov

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ARSET – Water Resources Management

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Applied Remote Sensing Training
Water Resource Management

NASA Earth Science Division NASA Applied Sciences Program

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Project Description

The goal of this NASA Applied Remote Sensing Education and Training project is to increase the utility of NASA Earth Science and model data for decision-makers and applied science professionals in the area of Water Resources Management Applications. The project conducts trainings and other capacity building activities on utilization of NASA satellite remote sensing and model data for a variety of water management applications including floods and snow related topics. Training activities are a combination of lectures and hands-on activities that teach professionals how to access, interpret, and apply NASA rainfall, snow, cloud, and atmospheric humidity products at regional and global scales with an emphasis of Case Studies. This website provides access to educational materials and regular updates on upcoming events and workshops.

If you would like more information about any of the activities and materials available on this site or to request a training please contact:
Ana.I.Prados@nasa.gov

Scheduled Trainings

Webinar Series: Flood and Drought Applications

November 6 to December 4, 2012
Each Tuesday

Session 1: 8:00 - 9:00 AM EST

Session 2: 2:00 - 3:00 PM EST - THIS SESSION IS FULL

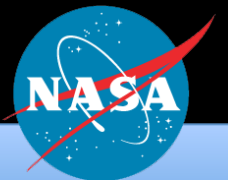
Course is FREE but registration is required. [Click here to register.](#)

[click here for agenda](#)

Stay Informed

Course Structure

- One lecture per week – every Tuesday between 16 January to 6 February
 - 16 January (2- 3 PM Eastern Time/11 AM – noon PST)
 - 23 January (2- 3 PM Eastern Time)
 - 30 January (2- 3 PM Eastern Time)
 - 6 February ((2- 3 PM Eastern Time)
- Presentations of all webinars can be found on:
<http://water.gsfc.nasa.gov/webinars/>
- Week-4 webinar by Tom Painter and Chris Mattmann from NASA/JPL
- Q/A sessions:
 - 23 January (3- 3:15 PM Eastern Time)
 - 30 January (3- 3:15 PM Eastern Time)
 - 6 February (3- 3:15 PM Eastern Time)
- ‘Chat Window’ and call-in number for Q/A during webinars



NASA Snow Products Training Overview

- *To provide a physical background for understanding the new directions in optical remote sensing and cryospheric/hydrologic sciences.*
- *To describe the MODSCAG fractional snow cover products.*
- *To describe the MODDRFS dust radiative forcing in snow products.*
- *To describe the Snow Data Server and data availability*
- *Ultimately to provide hands-on experience with these products in follow-on in-person courses.*

Introductions

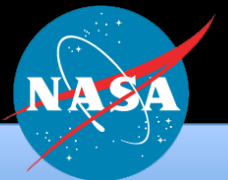
Thomas H. Painter

*PhD, Geography UC-Santa Barbara
BS, Mathematics, Colorado State U.*

Developed cutting edge remote sensing retrievals from multispectral and hyperspectral optical sensors.

Developed our understanding of dust radiative forcing on snowmelt and runoff in mountain systems.

AGU President Cryosphere Focus Group



Introductions

Christian Mattmann

*PhD, University of Southern California
BS, USC*

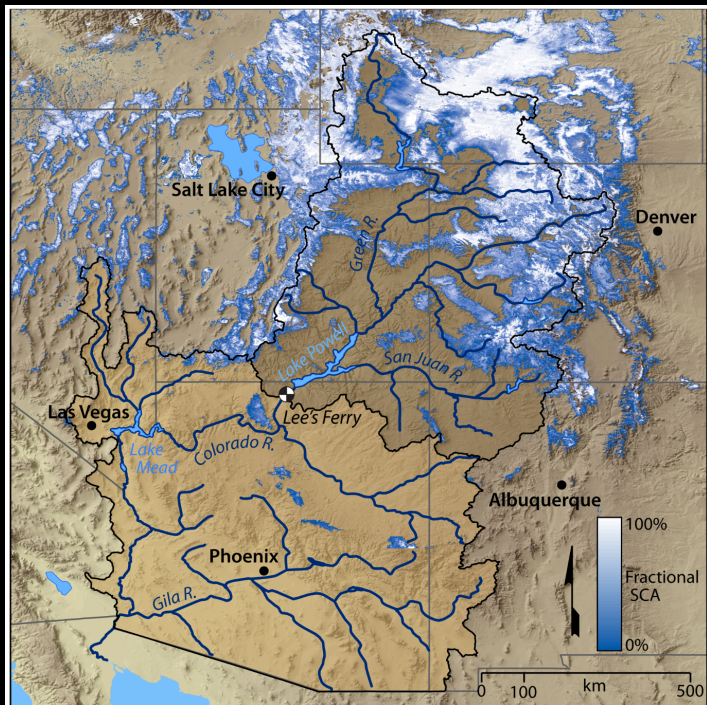
Senior Computer Scientist, Jet
Propulsion Laboratory

Software Architecture/Engineering
Professor, University of Southern
California

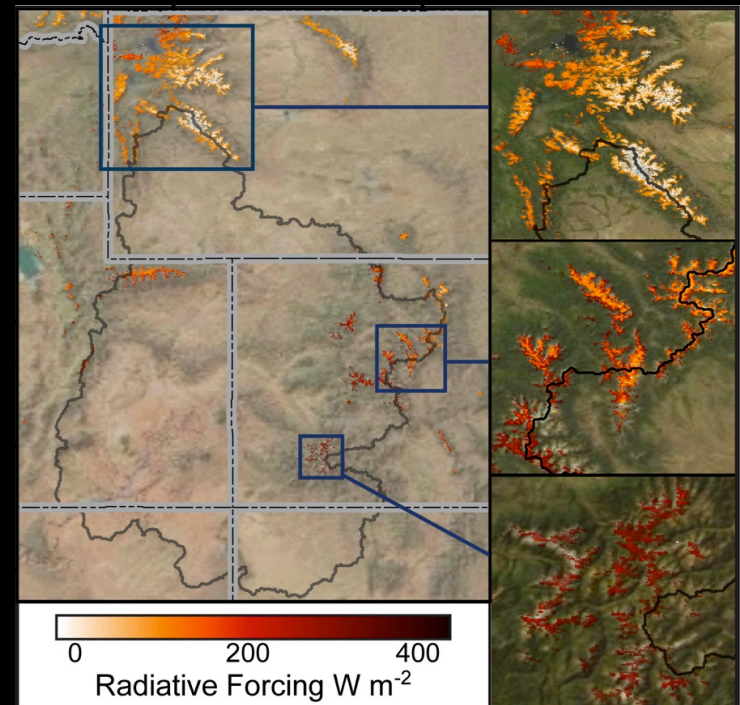


JPL Remote Sensing of Snow

MODIS Snow Covered Area and Grain size (MODSCAG)

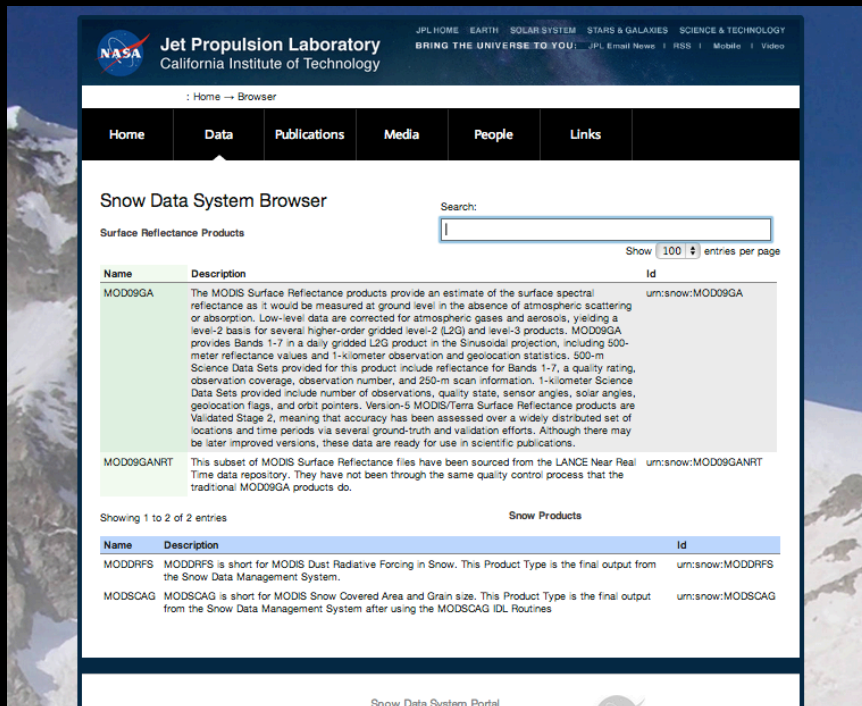


MODIS Dust Radiative Forcing in Snow (MODDRFS)



JPL Remote Sensing of Snow

MODIS historical processing



The screenshot shows the JPL Snow Data System Browser interface. At the top, the NASA Jet Propulsion Laboratory logo and navigation links are visible. Below the navigation bar, there is a search bar and a table of Snow Data System Products. The table lists two products: MOD09GA and MOD09GANRT. MOD09GA is described as the MODIS Surface Reflectance products, and MOD09GANRT is described as the subset of MODIS Surface Reflectance files sourced from the LANCE Near Real Time data repository. The interface also includes a 'Snow Products' section with a table listing MOD09RFS and MOD09SCAG.

Jet Propulsion Laboratory
California Institute of Technology

BRING THE UNIVERSE TO YOU

Home → Browser

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Snow Data System Browser

Search:

Surface Reflectance Products

Show 100 entries per page

Name	Description	Id
MOD09GA	The MODIS Surface Reflectance products provide an estimate of the surface spectral reflectance as it would be measured at ground level in the absence of atmospheric scattering or absorption. Low-level data are corrected for atmospheric gases and aerosols, yielding a level-2 basis for several higher-order gridded level-2 (L2G) and level-3 products. MOD09GA provides Bands 1-7 in a daily gridded L2G product in the Sinusoidal projection, including 500-meter reflectance values and 1-kilometer observation and geolocation statistics. 500-m Science Data Sets provided for this product include reflectance for Bands 1-7, a quality rating, observation coverage, observation number, and 250-m scan information. 1-kilometer Science Data Sets provided include number of observations, quality state, sensor angles, solar angles, geolocation flags, and orbit pointers. Version-5 MODIS/Terra Surface Reflectance products are Validated Stage 2, meaning that accuracy has been assessed over a widely distributed set of locations and time periods via several ground-truth and validation efforts. Although there may be later improved versions, these data are ready for use in scientific publications.	urn:snow:MOD09GA
MOD09GANRT	This subset of MODIS Surface Reflectance files have been sourced from the LANCE Near Real Time data repository. They have not been through the same quality control process that the traditional MOD09GA products do.	urn:snow:MOD09GANRT

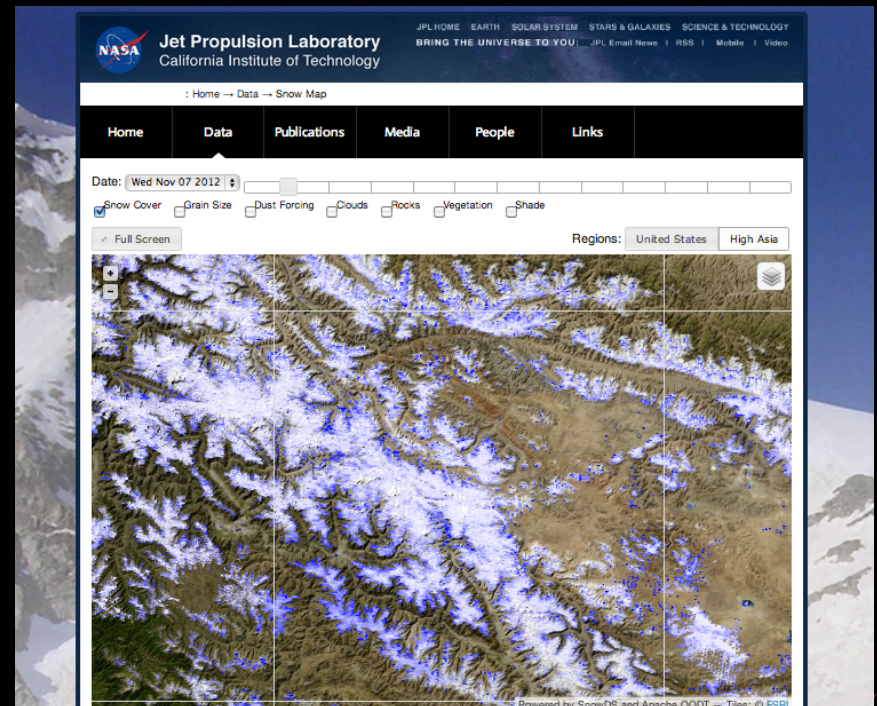
Showing 1 to 2 of 2 entries

Snow Products

Name	Description	Id
MOD09RFS	MOD09RFS is short for MODIS Dust Radiative Forcing in Snow. This Product Type is the final output from the Snow Data Management System.	urn:snow:MOD09RFS
MOD09SCAG	MOD09SCAG is short for MODIS Snow Covered Area and Grain size. This Product Type is the final output from the Snow Data Management System after using the MOD09SCAG IDL Routines	urn:snow:MOD09SCAG

Snow Data System Portal

MODIS Near Real Time (NRT) processing



The screenshot shows the JPL Snow Data System Browser interface for Near Real Time (NRT) processing. It features a date selector set to 'Wed Nov 07 2012' and a map of the United States with snow cover data. The map is overlaid with a grid and shows snow cover in white and blue. The interface includes a 'Full Screen' button and a 'Regions' dropdown menu set to 'United States' and 'High Asia'. The bottom of the page mentions 'Powered by SnowDS and Apache QODT' and 'Tiers: © ESRI'.

Jet Propulsion Laboratory
California Institute of Technology

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Home → Data → Snow Map

Home Data Publications Media People Links

Date: Wed Nov 07 2012

☒ Snow Cover ☐ Grain Size ☐ Dust Forcing ☐ Clouds ☐ Rocks ☐ Vegetation ☐ Shade

Full Screen

Regions: United States High Asia

Powered by SnowDS and Apache QODT — Tiers: © ESRI




JPL Snow Data Server

NASA Jet Propulsion Laboratory
California Institute of Technology

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Welcome to the Snow Data System

About This Site....

Welcome to the JPL Snow Data System. The Snow Data System serves cutting edge snow-related satellite and airborne remote sensing data, energy balance data for the Western US, and snow services targeting the snow, ice, climate, and water management communities.

For information about the project or comments, please contact:

Thomas Painter (thomas.painter@jpl.nasa.gov)

Chris Mattmann (chris.a.mattmann@nasa.gov)

Latest News

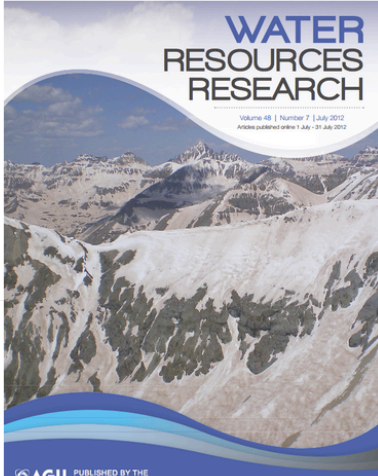
24.Sept.2012

[Avalanche on Manasku, Nepal](#)

15.Feb.2012

<http://www.nytimes.com/2012/02/16/science/earth-pushes-to-cut-emissions-that-speed-climate-change.html?ref=science>

Latest Images



AGU PUBLISHED BY THE AMERICAN GEOPHYSICAL UNION

NASA Jet Propulsion Laboratory
California Institute of Technology

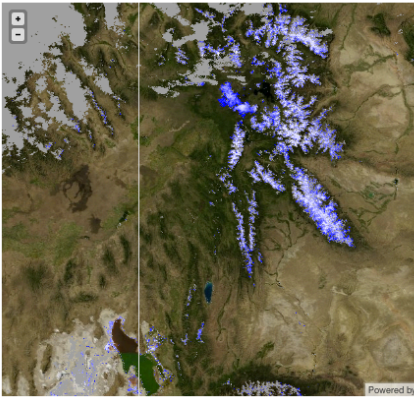
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Date: Wed Nov 07 2012 2012-11-07

☒ Snow Cover ☐ Grain Size ☐ Dust Forcing ☐ Clouds ☐ Rocks ☐ Vegetation ☐ Shade

Full Screen



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Data Western Energy Balance Of Snow

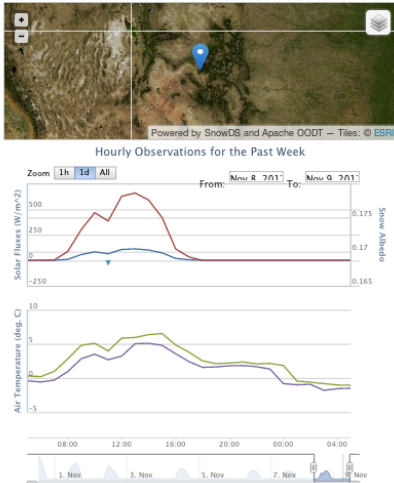
Grand Mesa Study Plot

39°3'2.956" N, -108°3'41.112" W

Grand Mesa Study Plot (GMSP) is located in an opening in a pine forest on the northern rim of Grand Mesa, at 3239m. Grand Mesa, located in western Colorado just east of Grand Junction, is the largest flat-topped mountain in the world with elevation ranging between 3000m and 3550m.

GMSP was established by the Snow Optics Laboratory (JPL) with funding from the US Geological Survey in October 2009 to augment measurements being made in Senator Beck Basin Study Area (SBBBSA) in the San Juan Mountains of southwestern CO, about 150 km south of GMSP. This site was chosen to capture spatial variability in dust loading and radiative forcing impacts. The high elevation of the mesa means that snowcover is established and maintained through out the winter and lasts longer than snow in the surrounding low lying terrain. All water from the mesa drains to the Colorado River through various tributaries.

The instrumentation array at GMSP is designed to measure snow energy balance similar to, but somewhat less extensive than, the two sites at SBBBSA. This site is equipped to measure incoming and outgoing solar (shortwave) and thermal (longwave) radiation fluxes, snowpack depth, wind speed and direction, air temperature, and humidity.



Hourly Observations for the Past Week

Zoom 1h 1d All From: Nov 8 2011 To: Nov 9 2011

Solar Fluxes (W/m²)

Air Temperature (deg. C)

Snow Albedo



<http://snow.jpl.nasa.gov/>

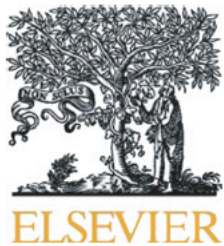
MODSCAG

Remote Sensing of Environment 113 (2009) 868–879

Contents lists available at [ScienceDirect](#)

Remote Sensing of Environment

journal homepage: www.elsevier.com/locate/rse



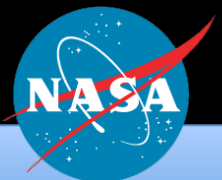
Retrieval of subpixel snow covered area, grain size, and albedo from MODIS

Thomas H. Painter^{a,*}, Karl Rittger^b, Ceretha McKenzie^c, Peter Slaughter^b, Robert E. Davis^c, Jeff Dozier^b

^a Department of Geography, University of Utah, Salt Lake City, UT 84112, USA

^b Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106, USA

^c US Army Cold Regions Research and Engineering Laboratory, Hanover, NH 03755, USA



MODSCAG

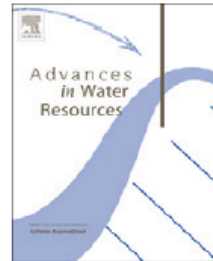
Advances in Water Resources xxx (2012) xxx–xxx



Contents lists available at [SciVerse ScienceDirect](#)

Advances in Water Resources

journal homepage: www.elsevier.com/locate/advwatres

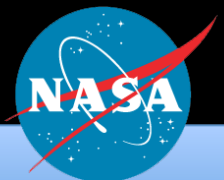


Assessment of methods for mapping snow cover from MODIS

Karl Rittger^a, Thomas H. Painter^b, Jeff Dozier^{a,*}

^aBren School of Environmental Science & Management, University of California, Santa Barbara, CA 93106-5131, United States

^bJet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr, Pasadena, CA 91109, United States



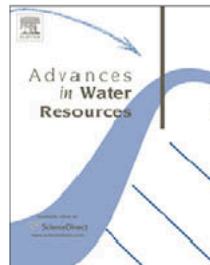
MODSCAG

Advances in Water Resources 31 (2008) 1515–1526

Contents lists available at [ScienceDirect](#)

Advances in Water Resources

journal homepage: www.elsevier.com/locate/advwatres

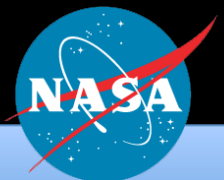


Time–space continuity of daily maps of fractional snow cover and albedo from MODIS

Jeff Dozier^{a,*}, Thomas H. Painter^b, Karl Rittger^a, James E. Frew^a

^a Donald Bren School of Environmental Science and Management, University of California, Santa Barbara, CA 93106-5131, United States

^b Department of Geography, University of Utah, Salt Lake City, UT 84112, United States



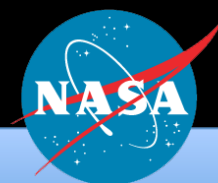
MODDRFS

GEOPHYSICAL RESEARCH LETTERS, VOL. 39, L17502, doi:10.1029/2012GL052457, 2012

Radiative forcing by light absorbing impurities in snow from MODIS surface reflectance data

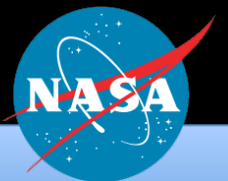
Thomas H. Painter,¹ Ann C. Bryant,² and S. McKenzie Skiles³

Received 18 June 2012; revised 18 July 2012; accepted 23 July 2012; published 11 September 2012.



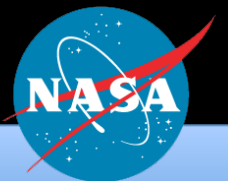
Training overview

- Remote sensing foundations
- MODSCAG
- MODDRFS
- SnowMap utilities



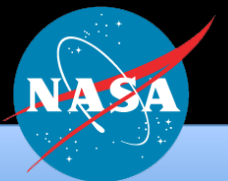
Remote Sensing Foundations

Thomas H. Painter, Chris Mattmann
NASA Jet Propulsion Laboratory
California Institute of Technology

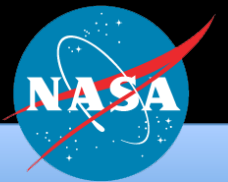


Outline

- 1 Satellite Foundations
- 2 Sun-Atmosphere-Earth Interactions
- 3 Snow Hydrology
- 4 Snow Optical Properties
- 5 Snow Reflectance

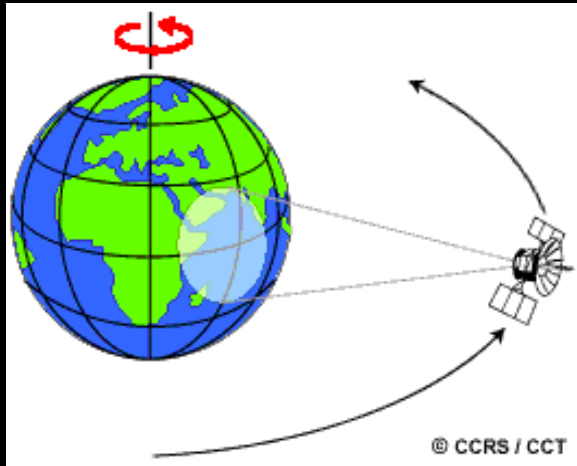


SATELLITE FOUNDATIONS



Types of satellite orbits

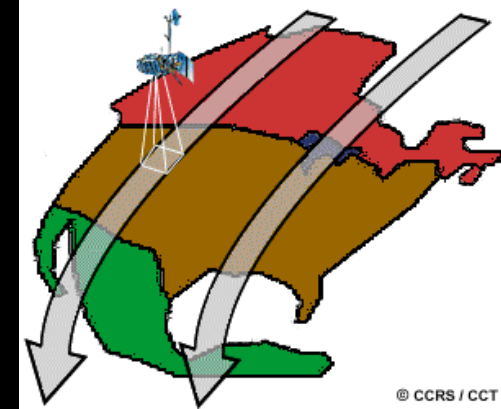
Geostationary orbit



- Fixed above earth at ~36,000 km
- Frequent Measurements
- Limited Spatial Coverage

Low Earth Orbit (LEO)

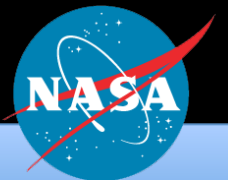
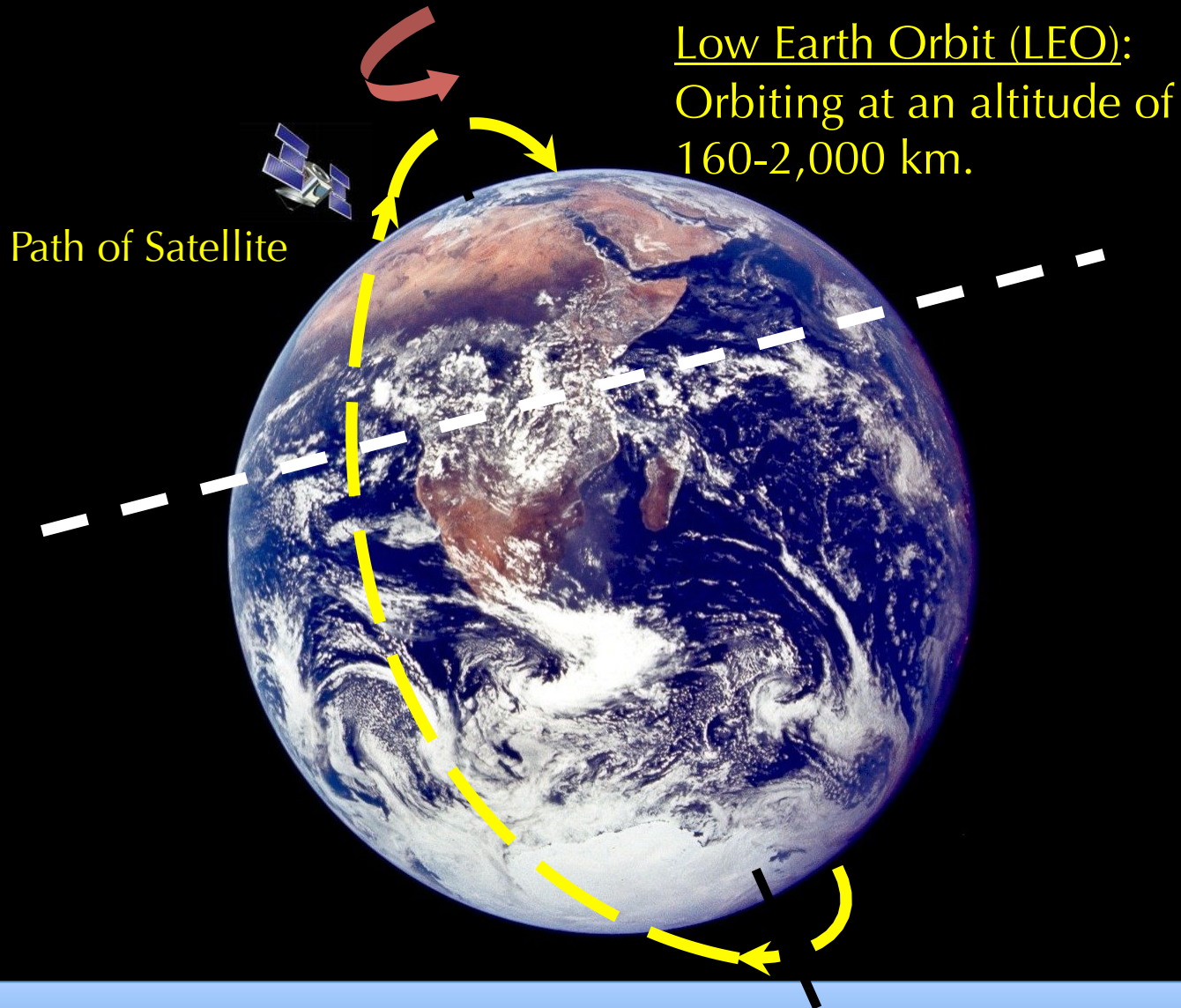
- Polar (Terra)
- Nonpolar (TRMM)



- Circular orbit constantly moving relative to the Earth at 160-2000 km
- Less Frequent measurements (< 2 times per day)
- Large (global) spatial coverage
- Better spatial resolution

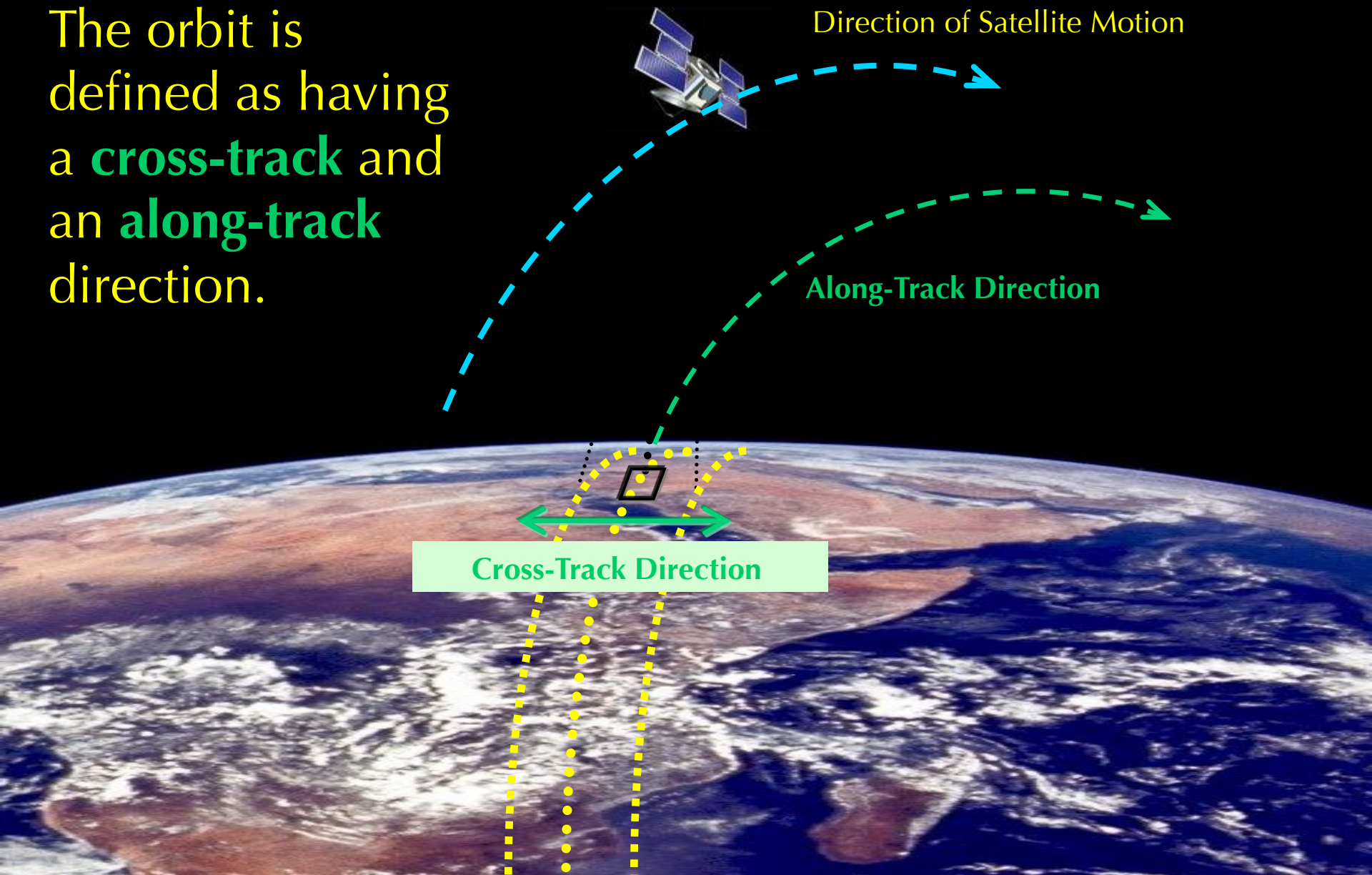


Low-Earth Orbits (LEO)

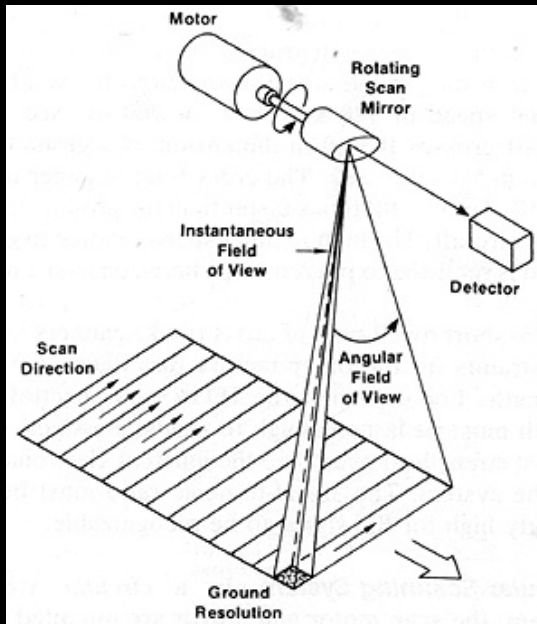


LEO Field-of-View (FOV)

The orbit is defined as having a **cross-track** and an **along-track** direction.



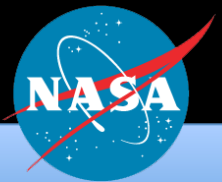
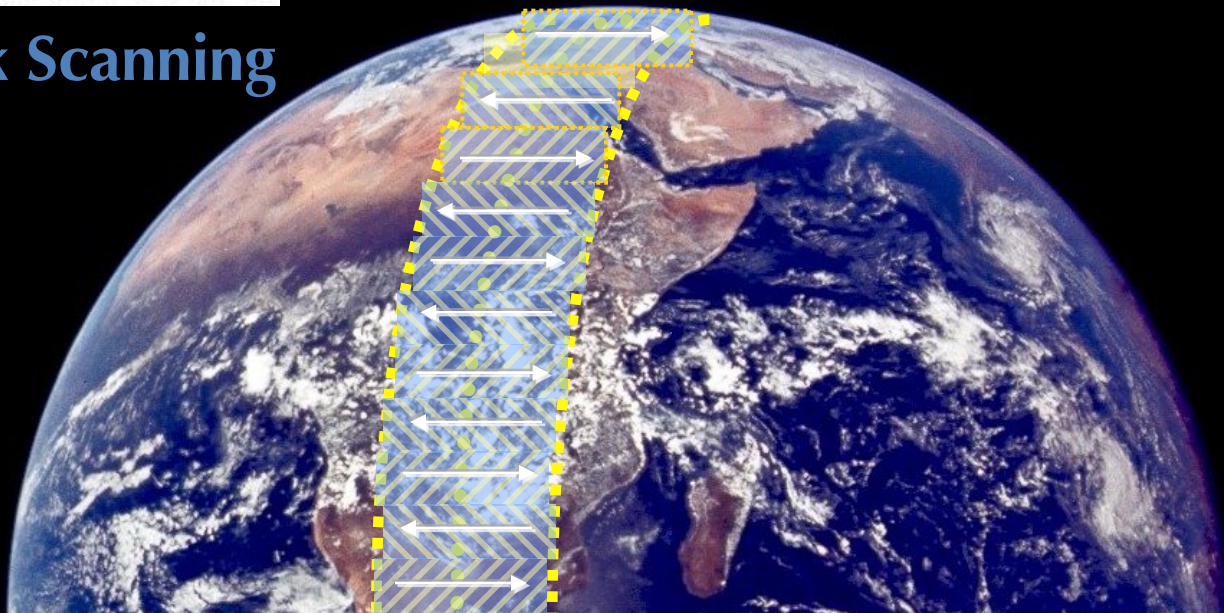
Earth-Observing Satellites



“Cross-Track Scanning,”
Scan mirror swings back and forth.

Sensor observes pixels in sequence across track and along the direction of the satellite's motion.

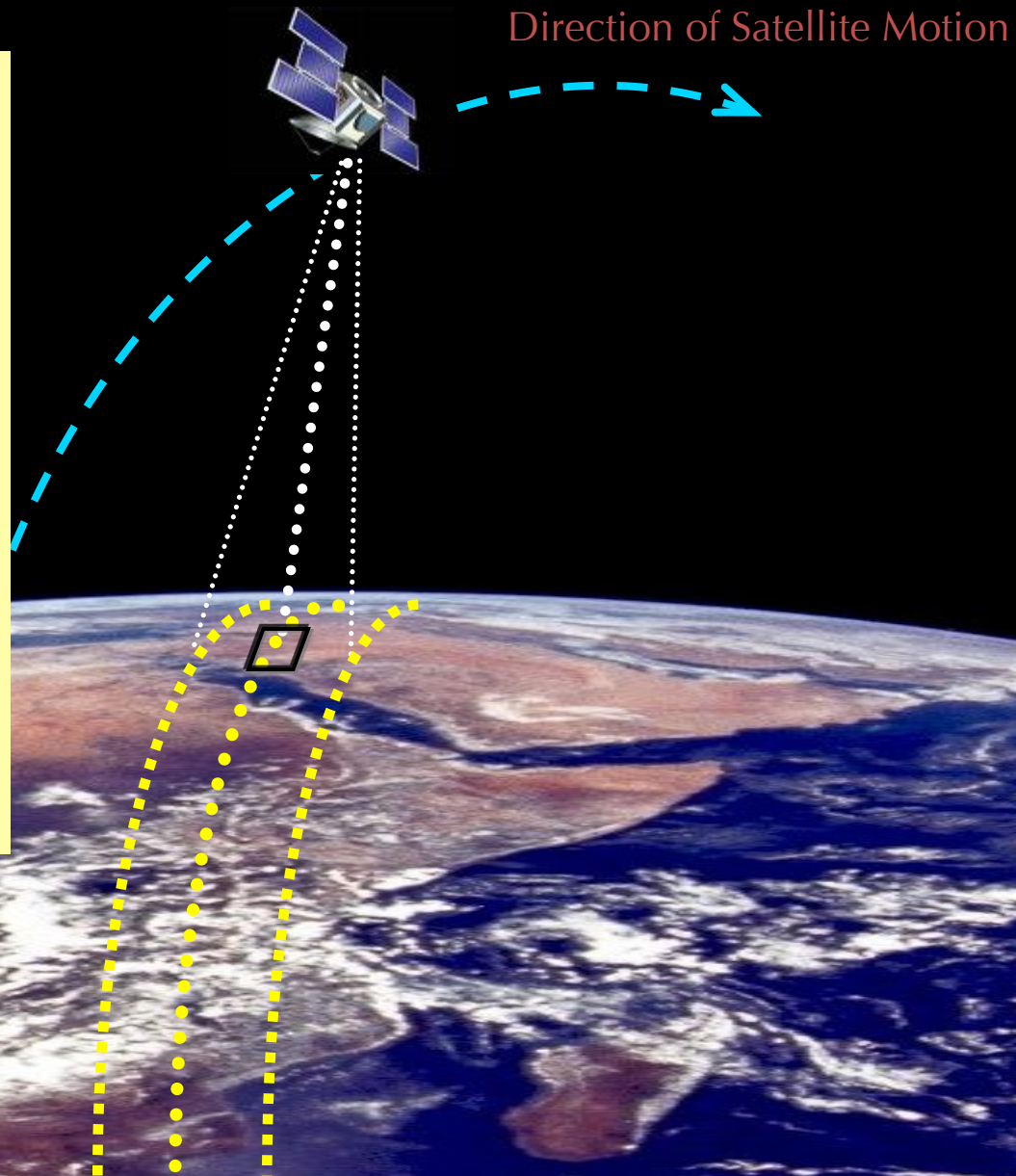
Cross-Track Scanning



LEO Field-of-View (FOV)

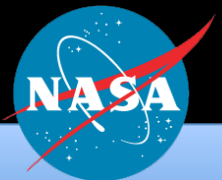
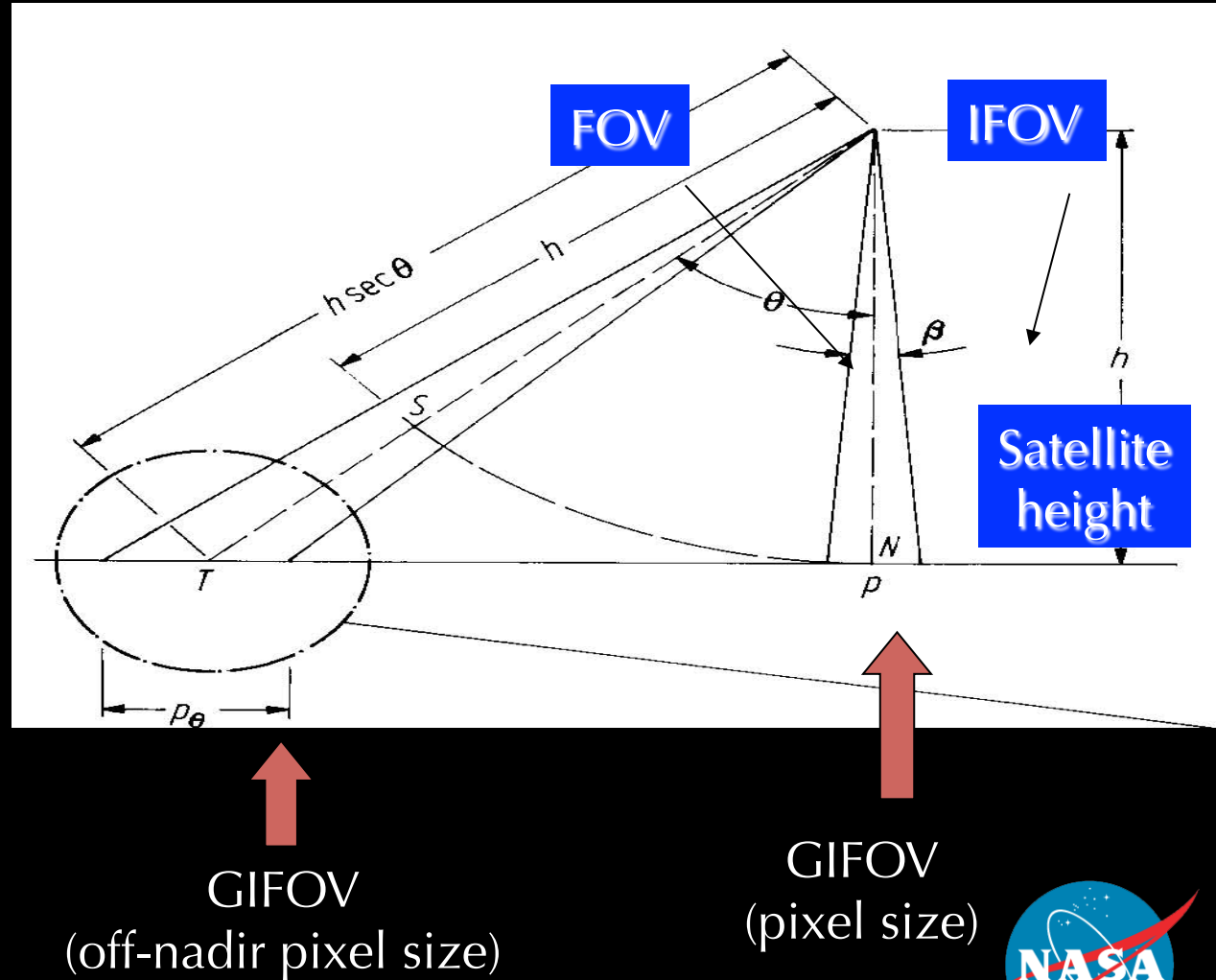
Satellites in Low Earth Orbit have an **instantaneous field-of-view (IFOV) (angular)**
- independent of LEO altitude

At the ground, it is the **ground instantaneous field-of-view (GIFOV) (distance)**
- depends on LEO altitude



Spatial Resolution

- Spatial Resolution : A simple definition is the pixel size that satellite images cover.
- Satellite images are organized in rows and column called raster imagery and each pixel has a certain spatial resolution.

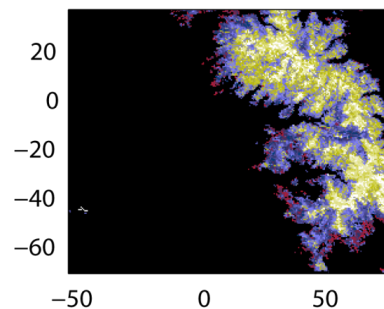
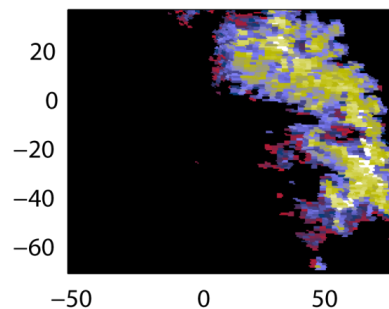
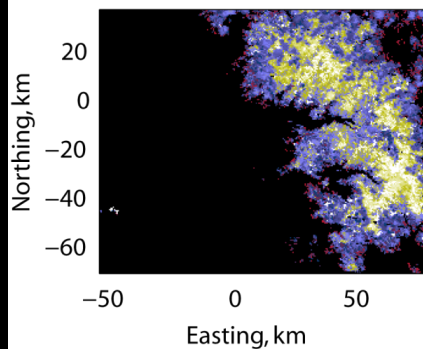


08 Apr 2007

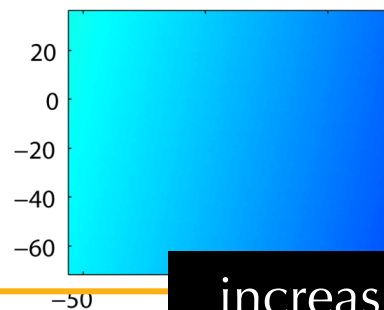
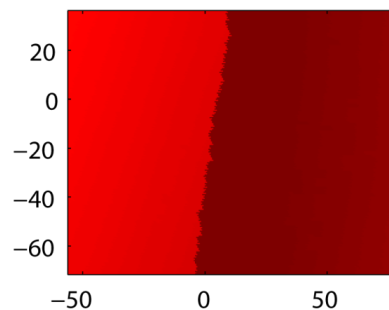
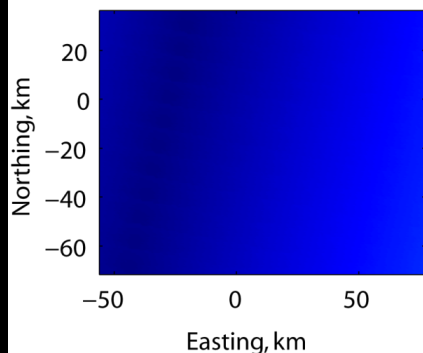
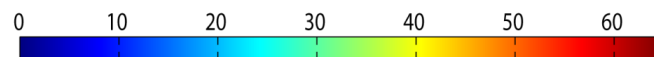
09 Apr 2007

10 Apr 2007

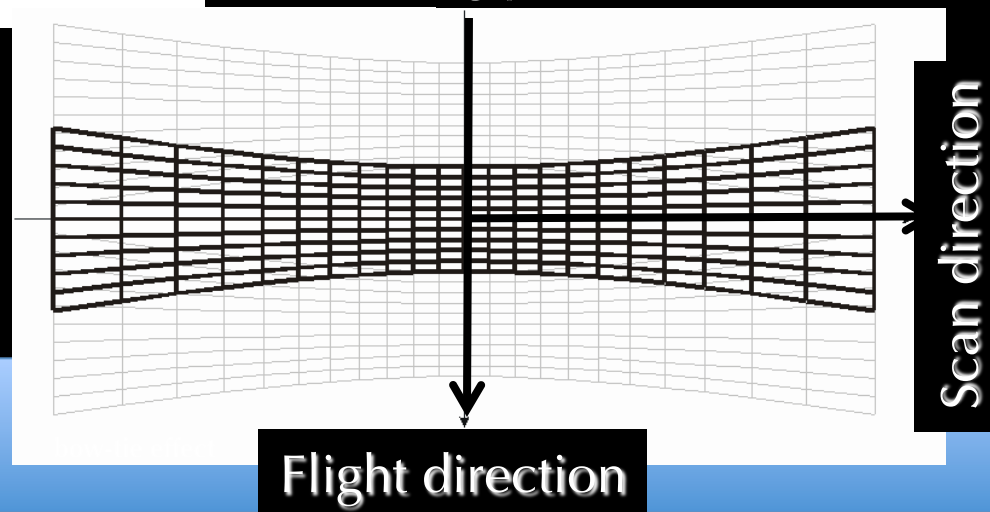
Fractional snow-covered area



View angle to sensor, from zenith



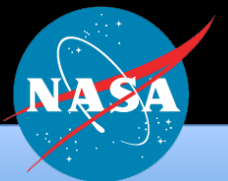
increasing pixel size



Temporal Resolution of Remote Sensing Data

The frequency at which data are obtained is determined by:

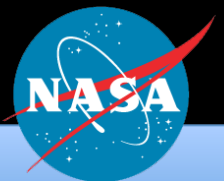
- Type and height of orbit
- Size of measurement swath



Temporal resolution of Polar Orbiting Satellites

Example: Terra, Aqua

- Observations available only at the time of the satellite overpass.
- IR based observations available 2X a day
- Visible observations available 1X a day
- Polar regions may have several observations per day.



Remote Sensing – Resolutions

Spectral resolution – The number and range of spectral bands.

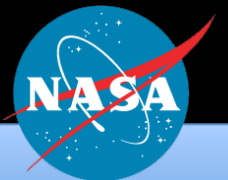
More bands = More information

Radiometric resolution – The bandwidth of the individual spectral bands.
Important for avoiding or taking advantage of “atmospheric windows”

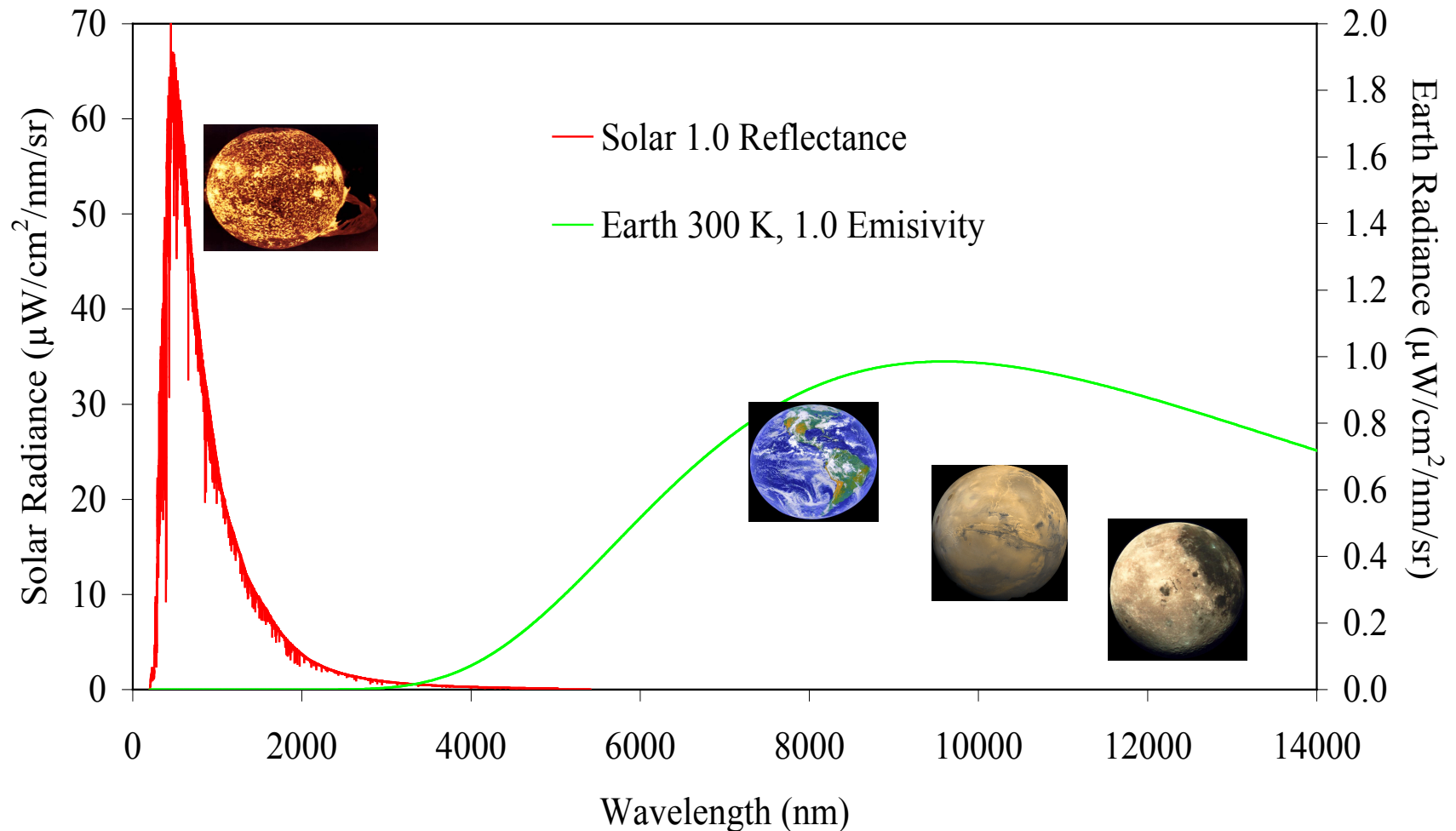
Spectral dynamic range – The range of radiances in which change in radiance can be detected. This is critical for snow in particular because with many sensors (e.g. Landsat Thematic Mapper), snow's reflected radiance saturates the sensor's detection at reflectances well below actual. In spectral mixture analysis and physical retrievals, the signal is contaminated or inaccessible.



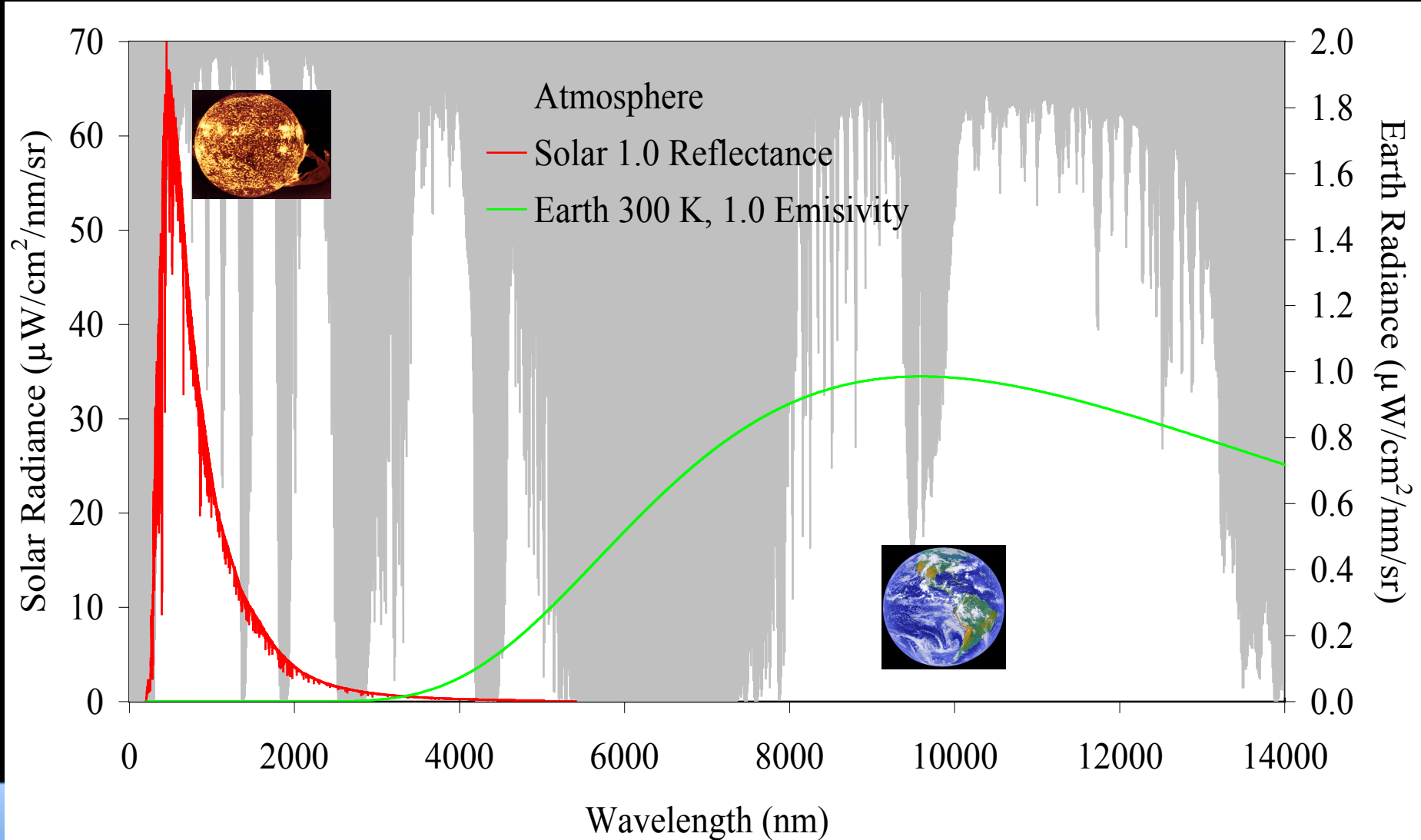
SUN-ATMOSPHERE-EARTH RADIATION INTERACTIONS



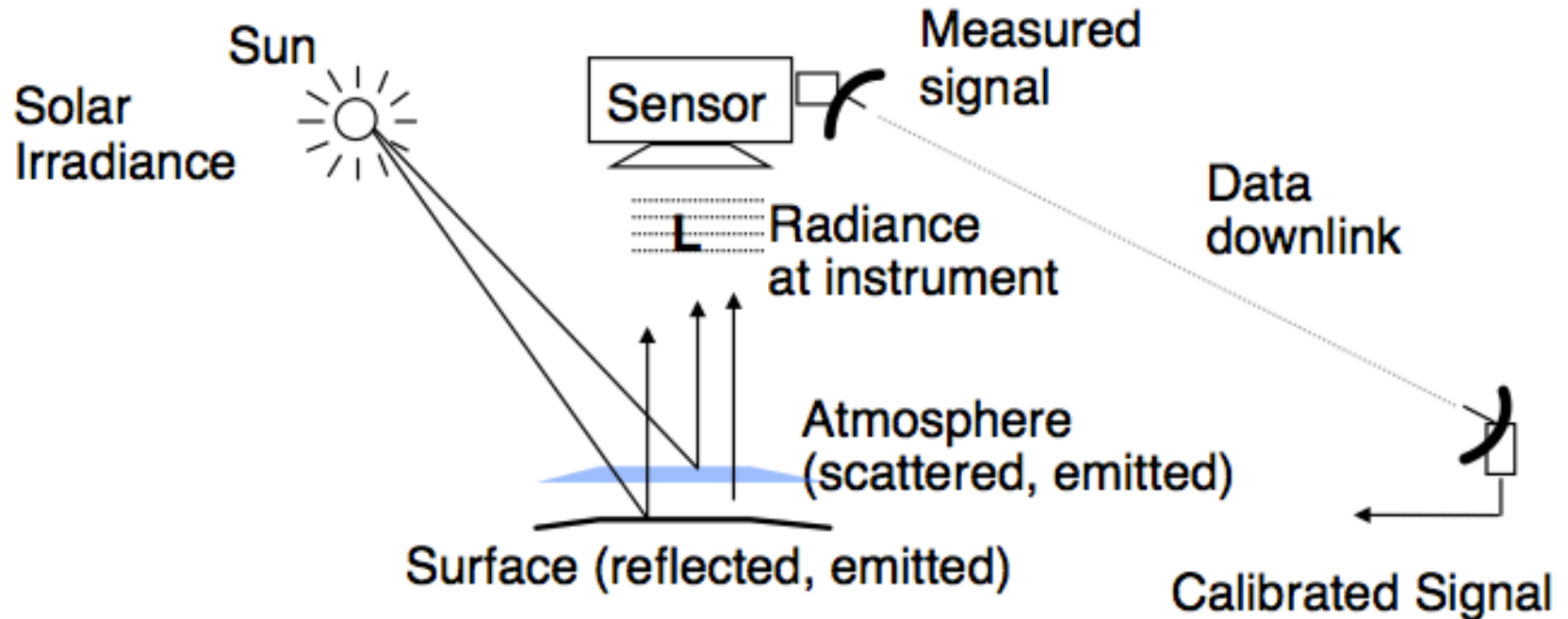
Available Signal in the Optical Spectrum



Transmittance of the Atmosphere



The Available Signal and Approach



Energy is emitted by the Sun as well as planet sources

The energy is transmitted and scattered by the atmosphere and reflected from the surface

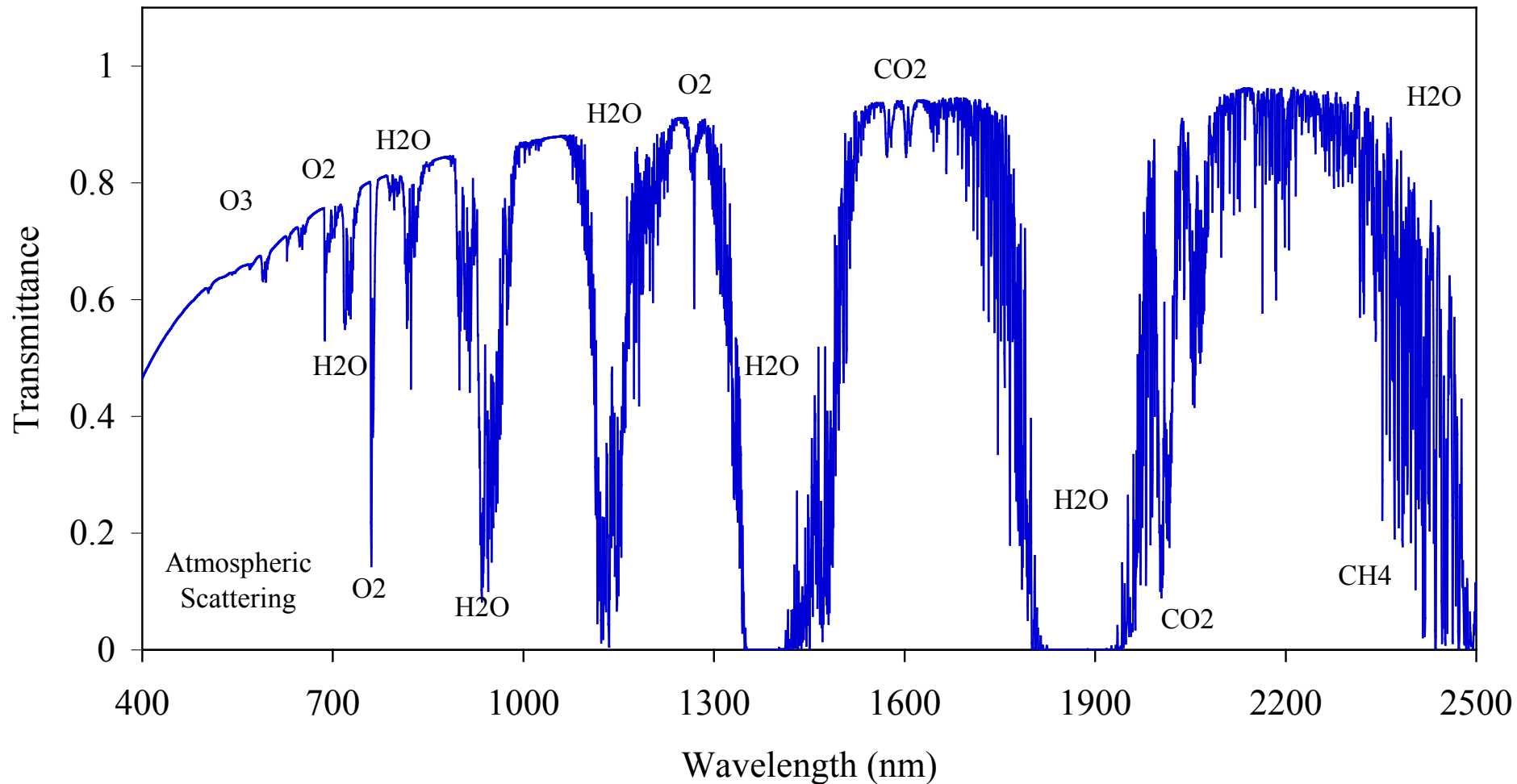
The imaging sensor responds to the energy (L) within a field-of-view and spectral range

Sensor signal is digitized and relayed to the ground and recorded

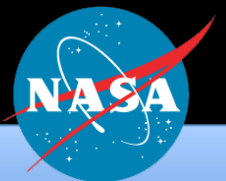
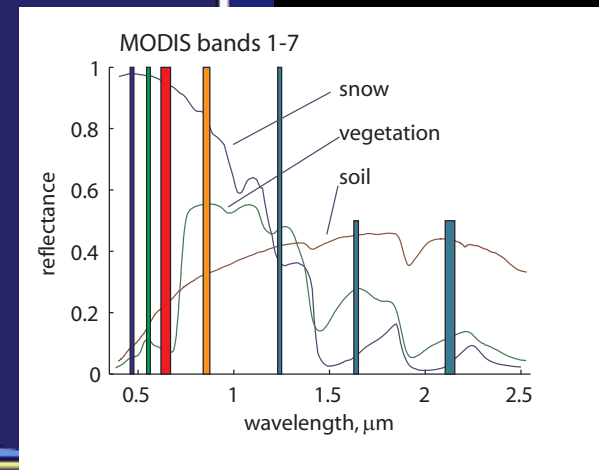
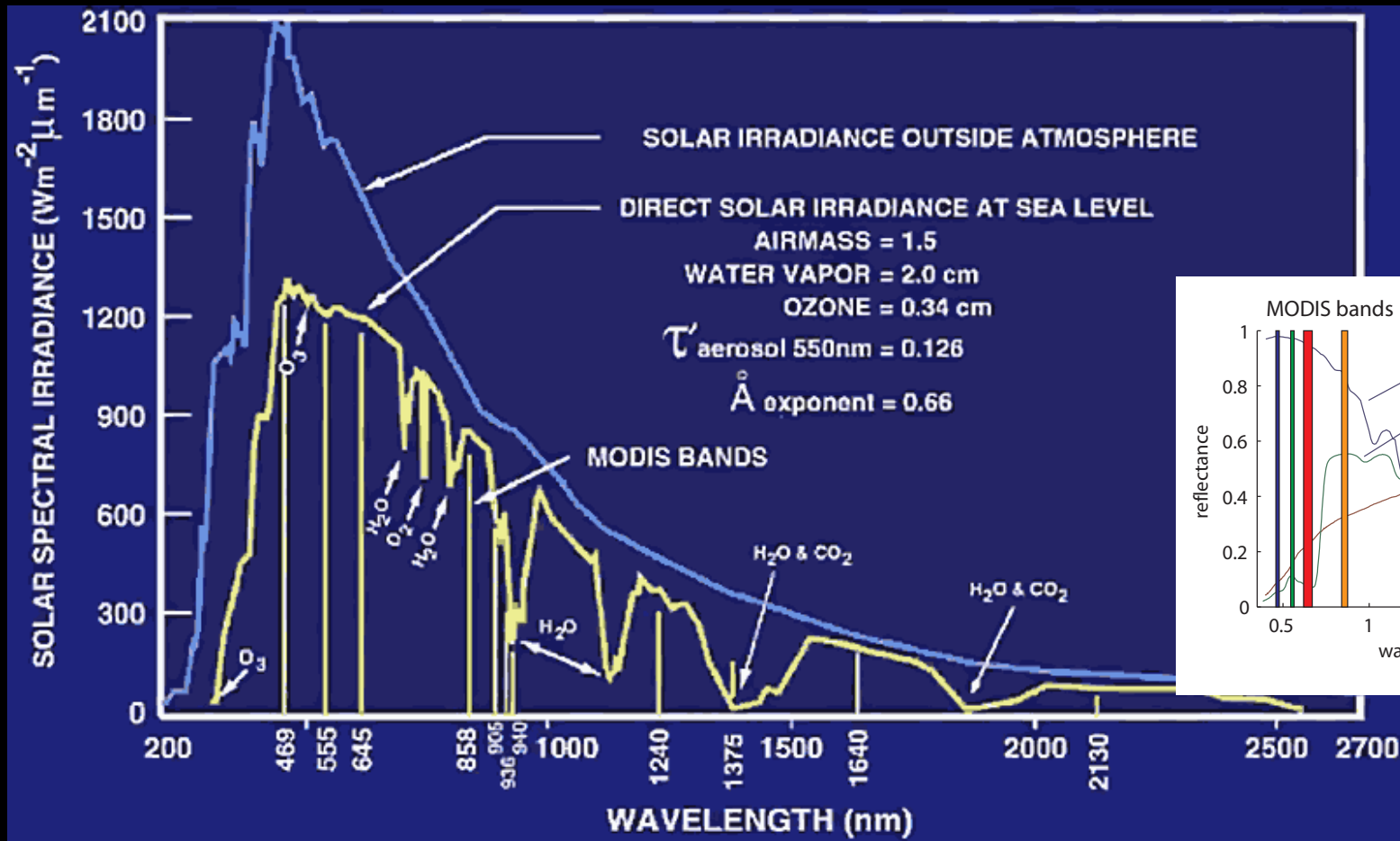
The signal is calibrated, processed, and analyzed to answer the questions of interest



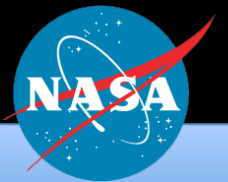
Transmittance of the Atmosphere



MODIS spectral irradiance



SNOW OPTICAL PROPERTIES

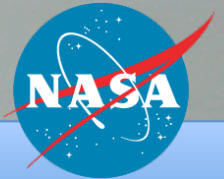


Mountain Snow

Snow albedo The total reflectivity of snow to all incoming sunlight

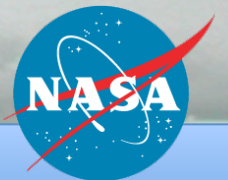
Snow spectral albedo The total reflectivity of snow to all incoming sunlight in a particular wavelength (color) range

HDRF Hemispherical-directional reflectance factor – this is how the angular distribution of snow-reflected sunlight varies relative to a perfectly diffuse surface

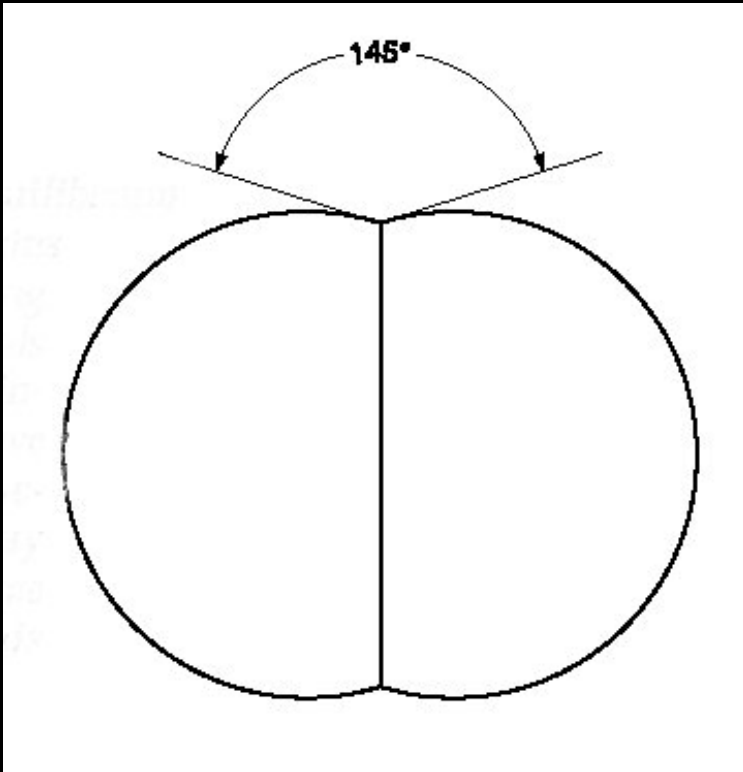


Mountain Snow

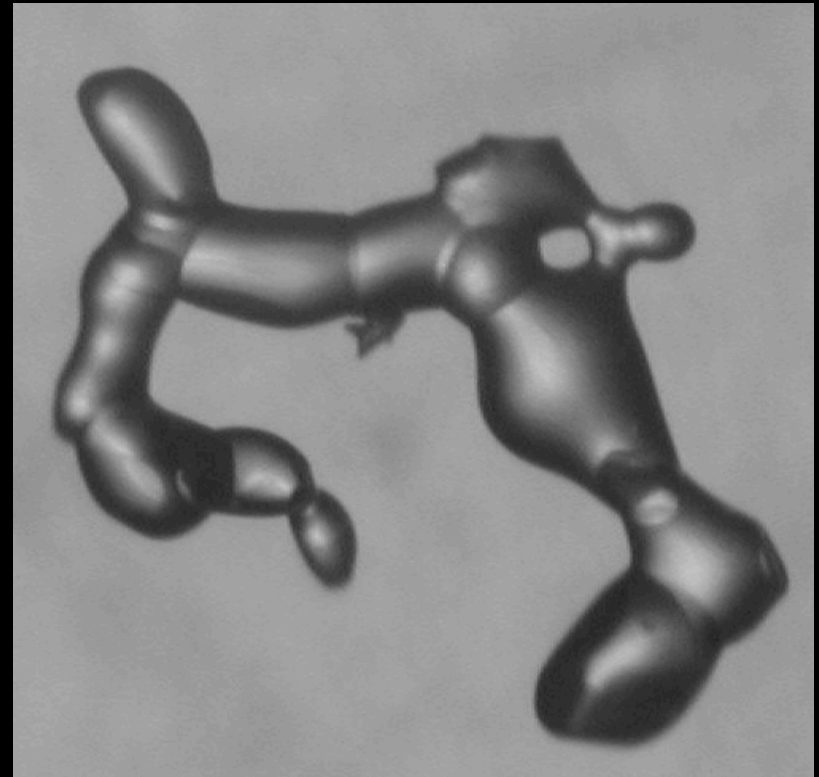
Snow metamorphism the evolution of snow particle shape and dimensions after falling from the sky



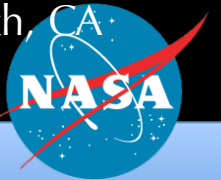
Dry Snow Metamorphism



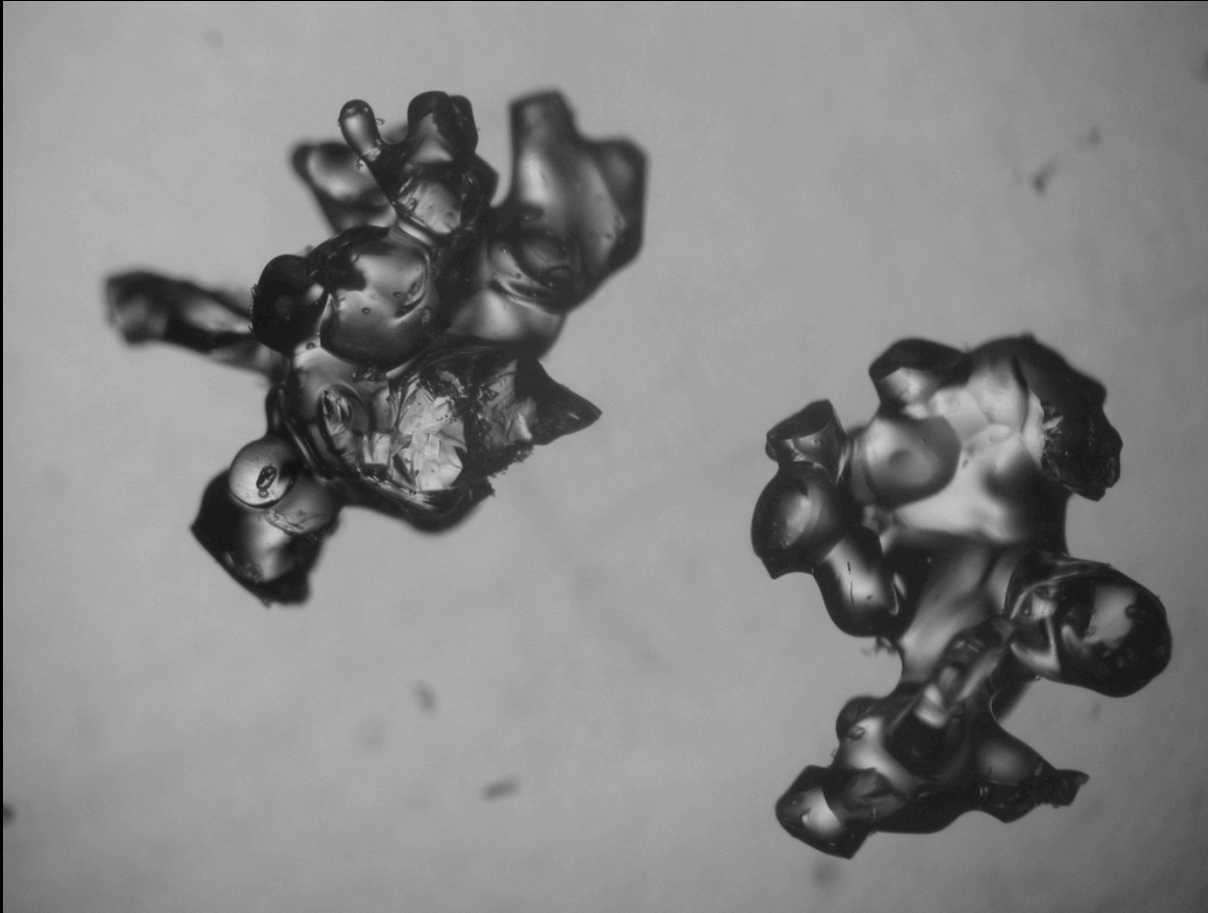
From Colbeck (CRREL 1997)



20 day old dry snow – Mammoth, CA



Wet Snow Metamorphism



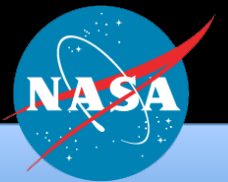
Melt-freeze grains
Mammoth, CA
Winter, 2001

Snow Metamorphism

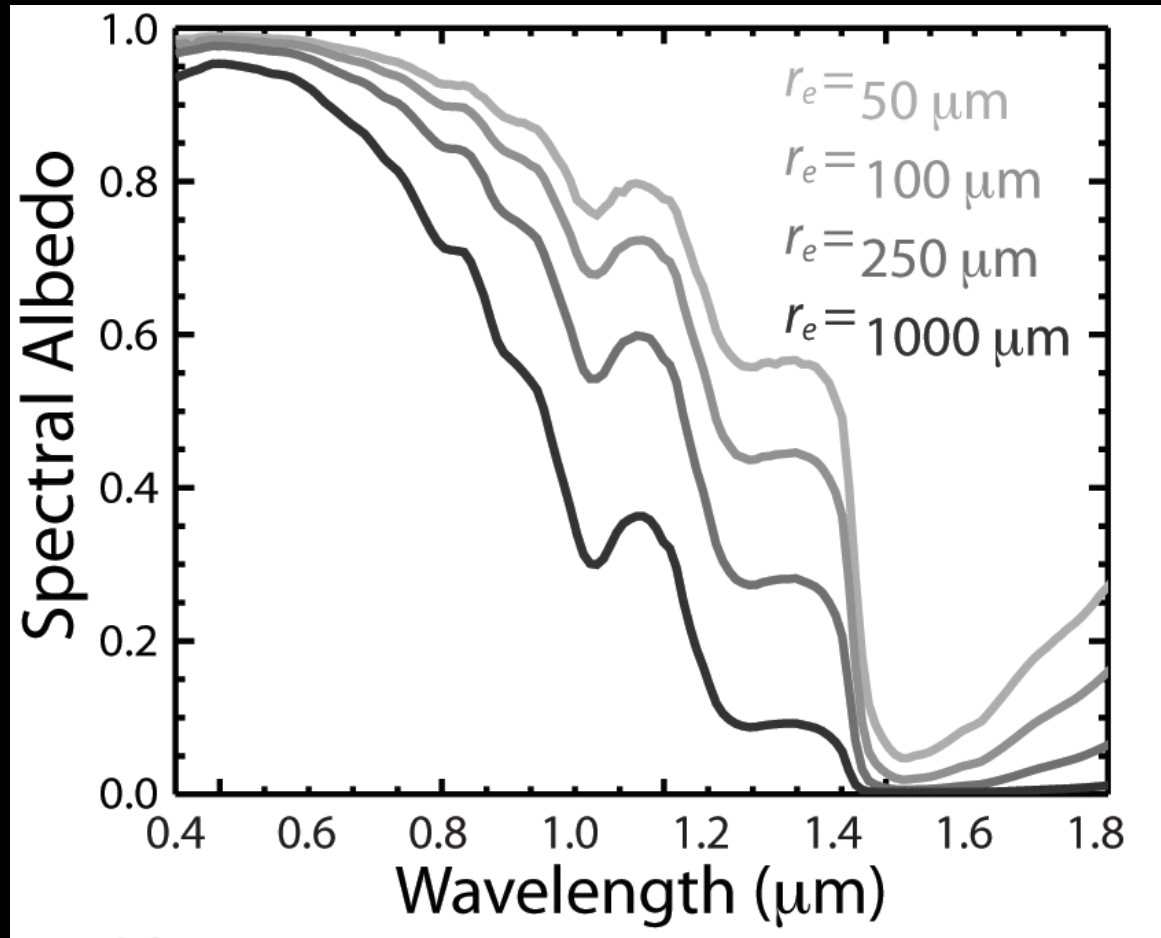
- Snow metamorphism has monotonic decrease in the ratio of surface area to volume
- Absorbing path length (grain size) has monotonic increase
- Metamorphism is more rapid at higher temperatures
- Metamorphism is even more rapid in the presence of liquid water



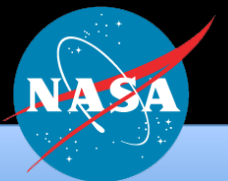
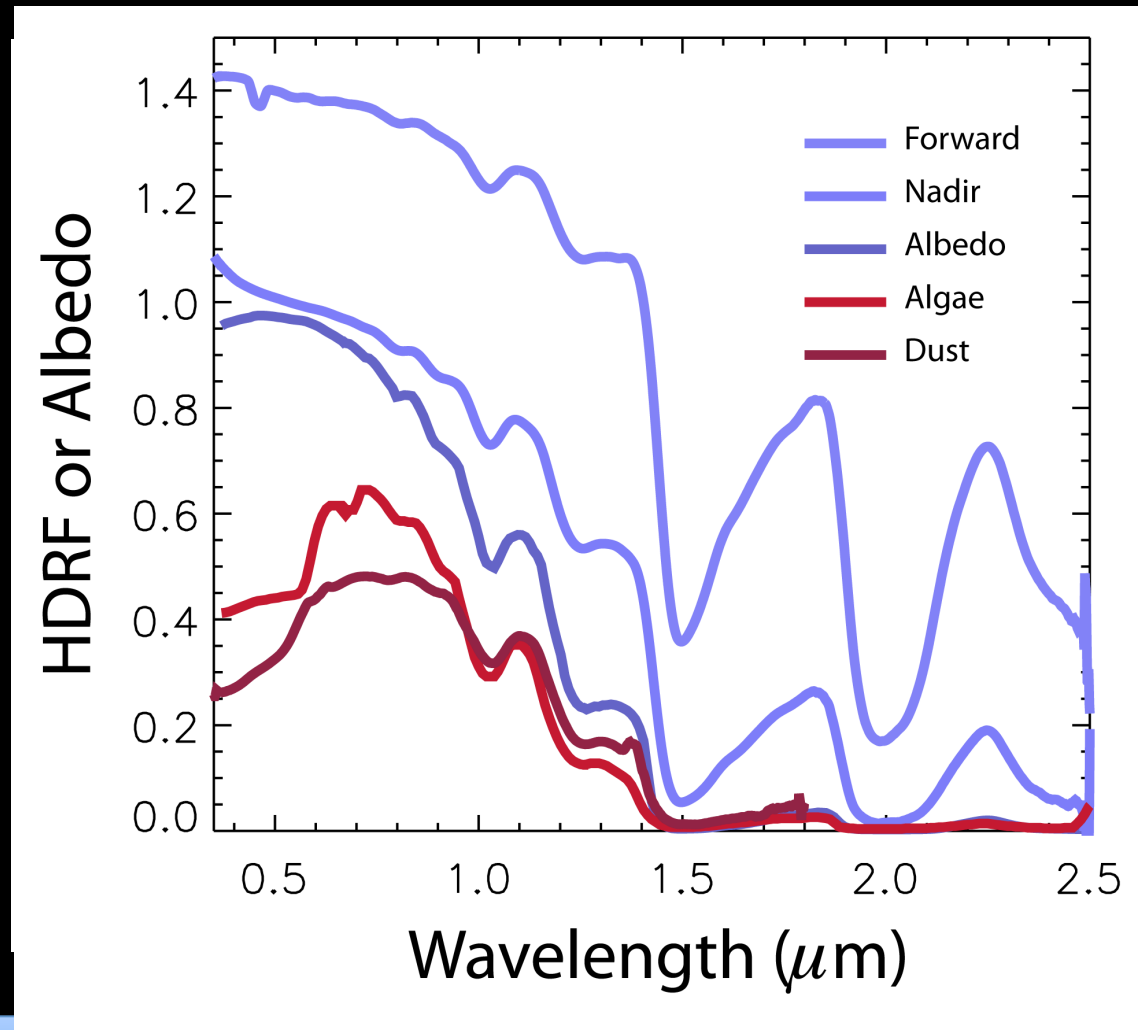
Snow – A Low Flying, Big Particle Cloud



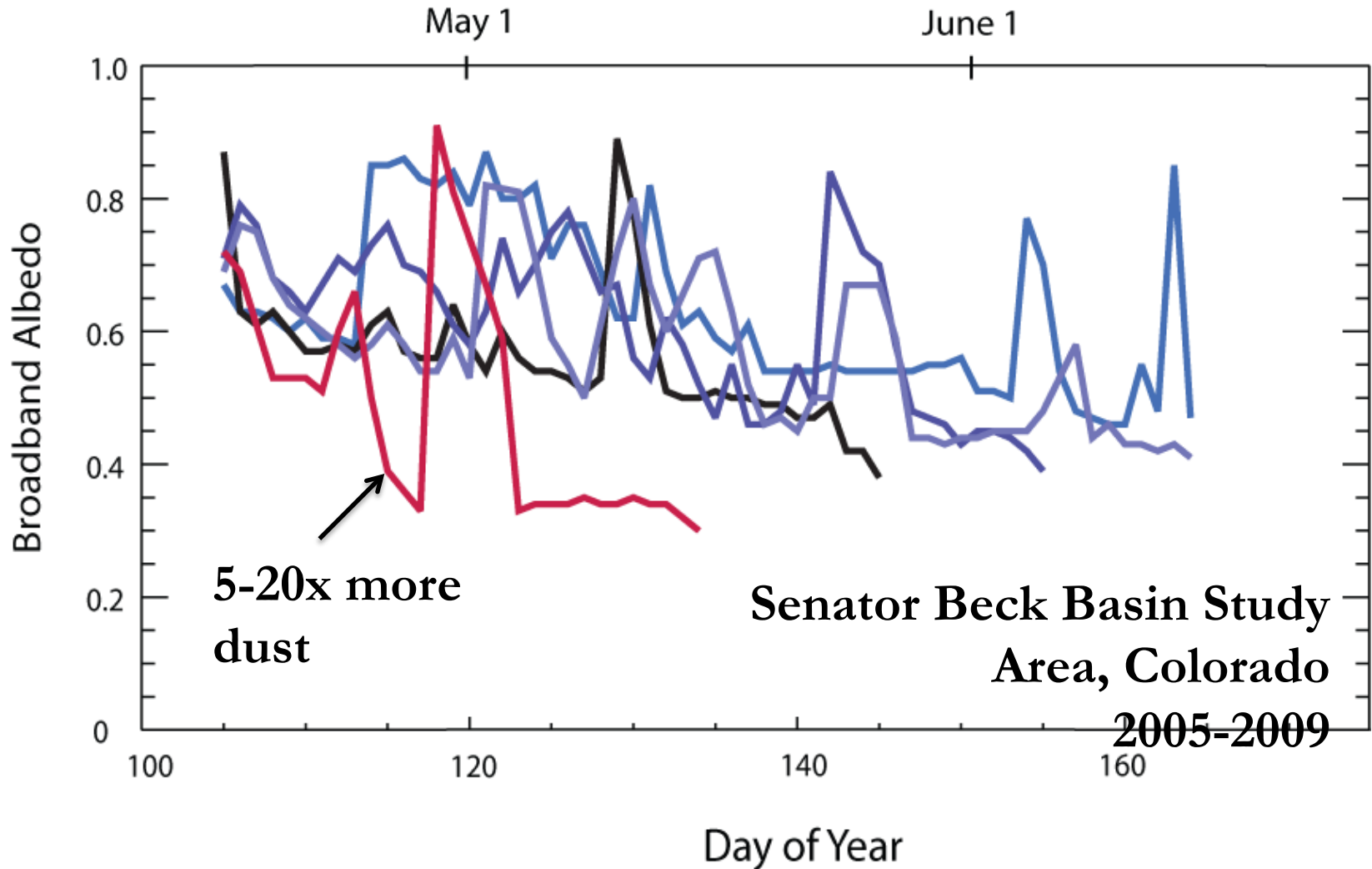
Snow Reflectance



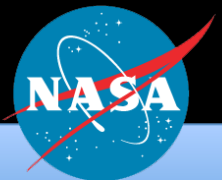
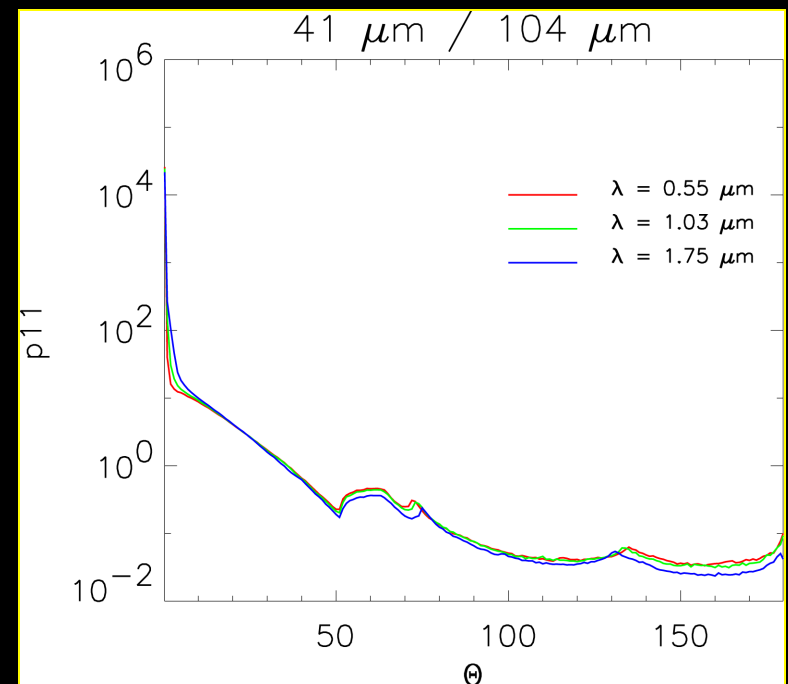
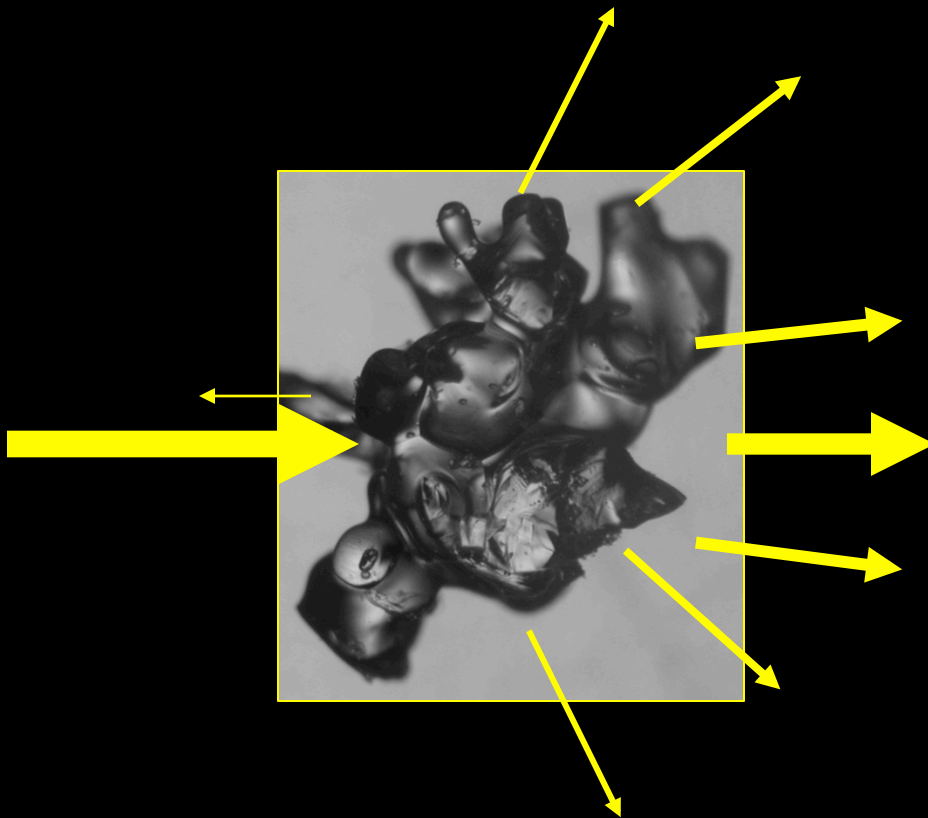
The Earth's Most Colorful Surface



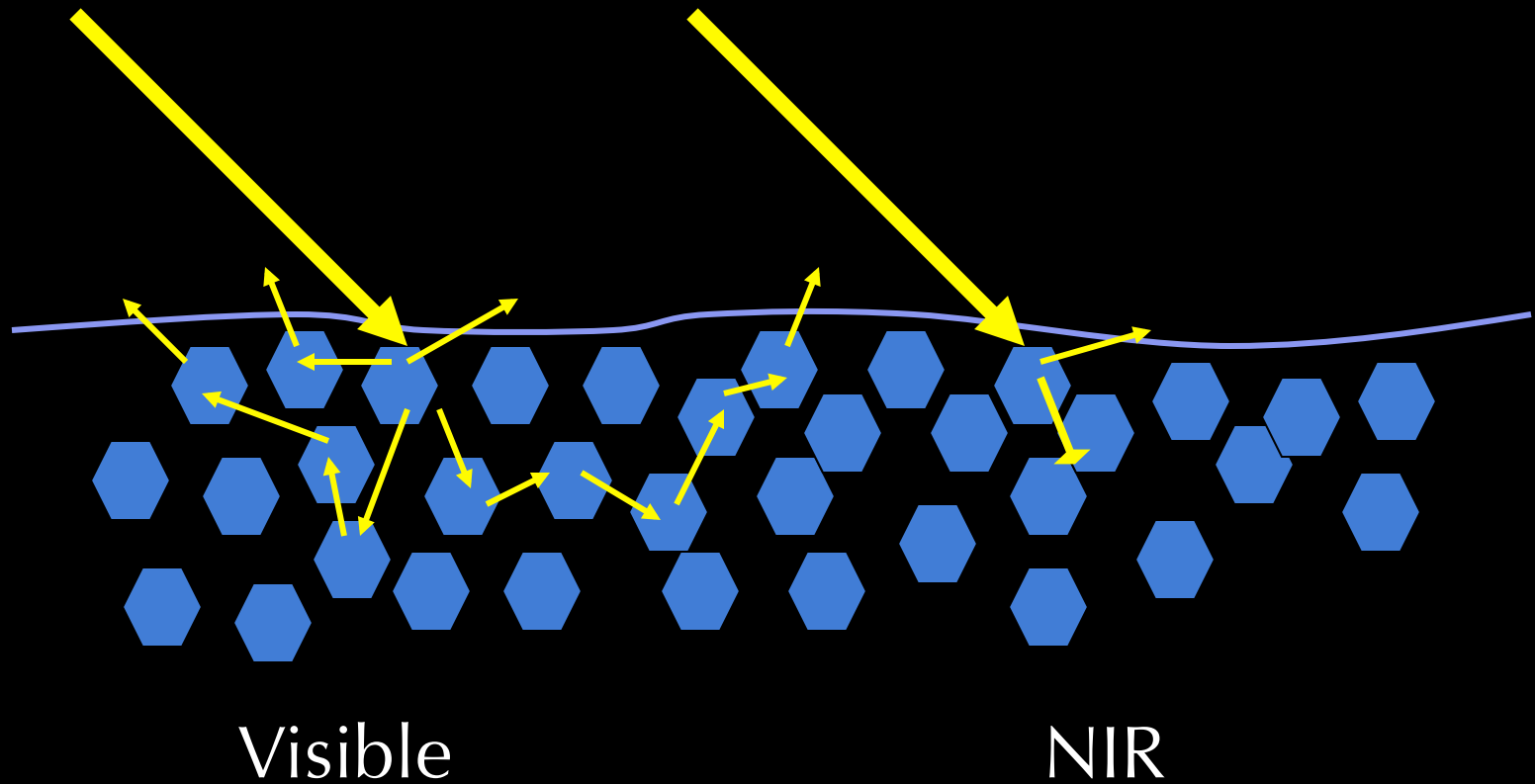
Albedo



Single Scattering



Multiple Scattering



Radiative Transfer Equation

Change in radiation
intensity with
change in optical
depth through
medium

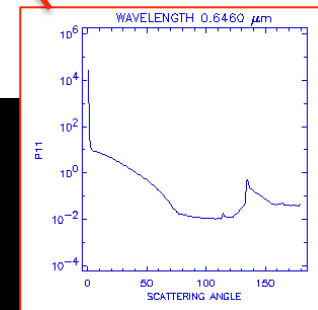
Beam

Emission

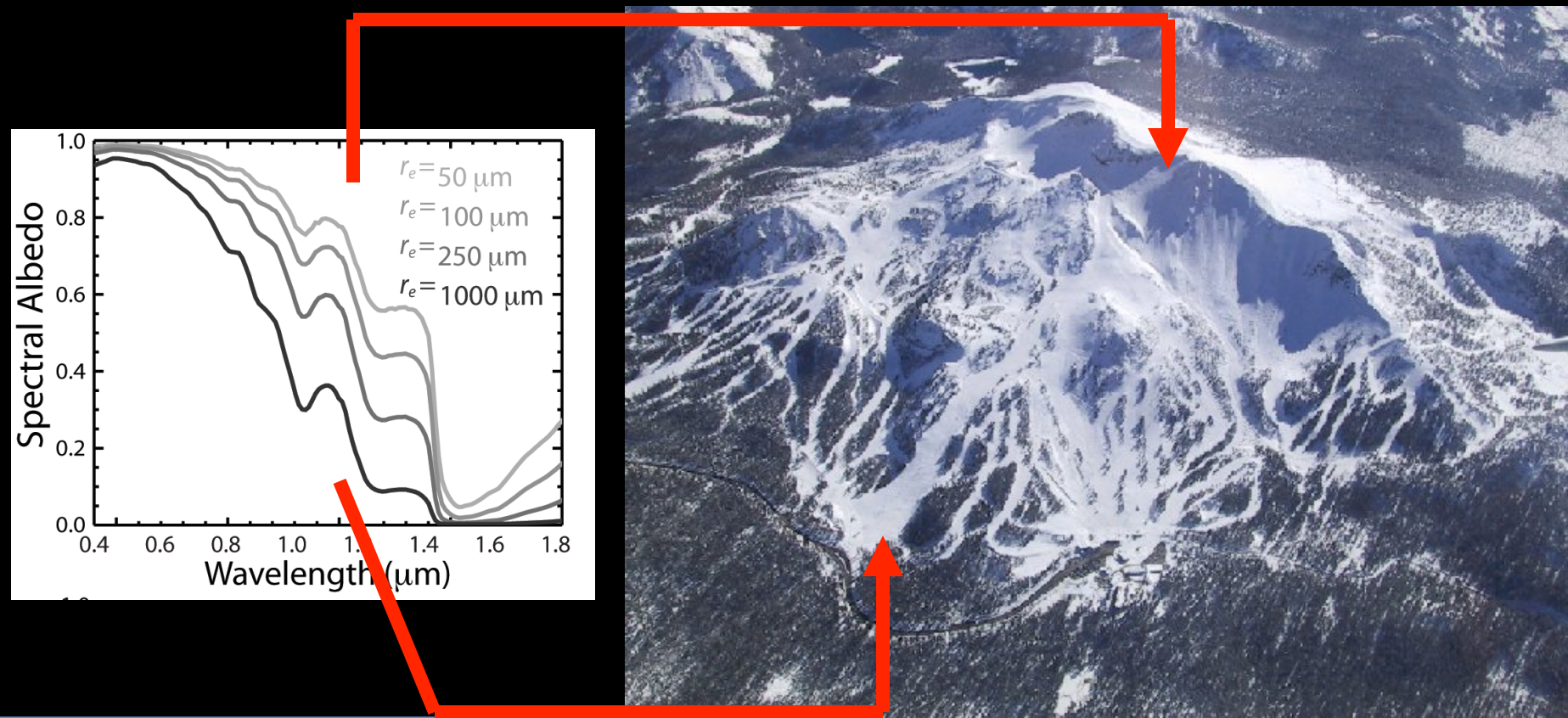
Scattering

$$\mu \frac{dl(\tau, \mu, \phi)}{d\tau} = l(\tau, \mu, \phi) - [1 - \omega(\tau)] B(T(\tau)) - \frac{\omega(\tau)}{4\pi} \int_0^{2\pi} d\phi' \int_{-1}^1 p(\tau, \mu, \phi; \mu', \phi') l(\tau, \mu', \phi') d\mu' - \frac{\omega(\tau) I^{inc}}{4\pi} p(\tau, \mu, \phi; -\mu_o, \phi_o) e^{-\tau/\mu_o}$$

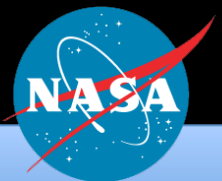
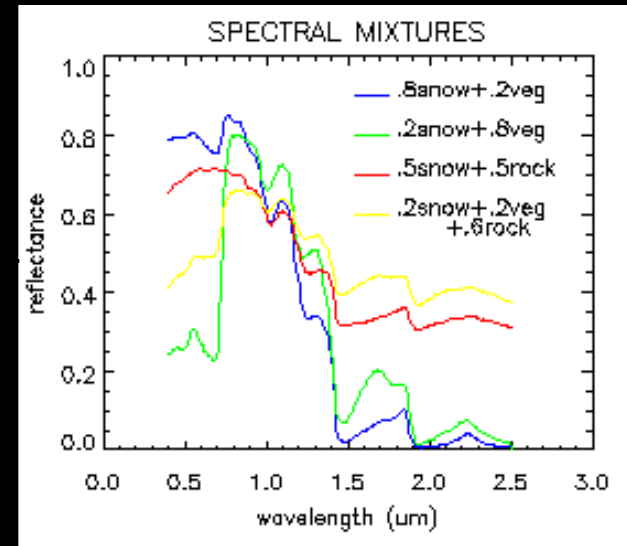
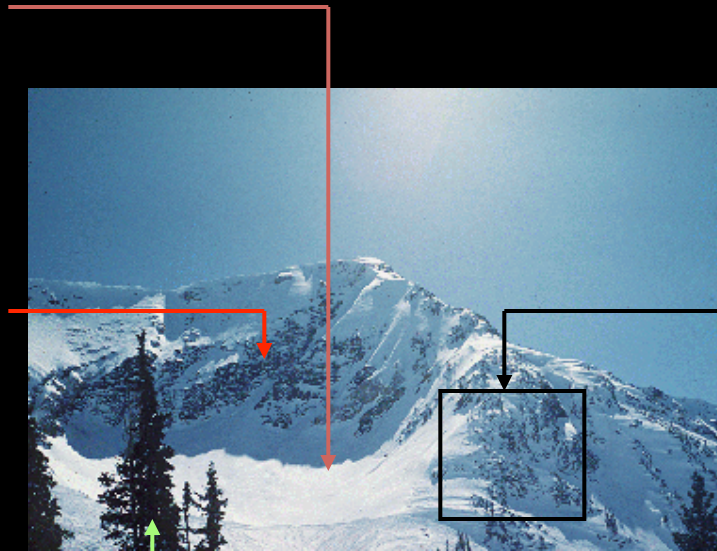
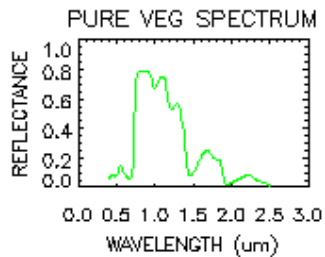
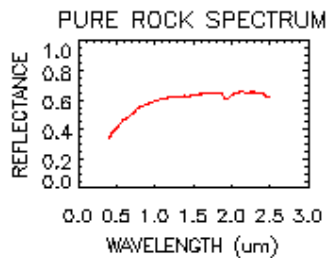
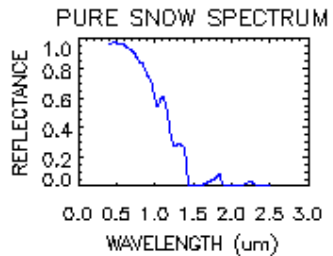
**Beam
Scattered**



Spectral Gradients



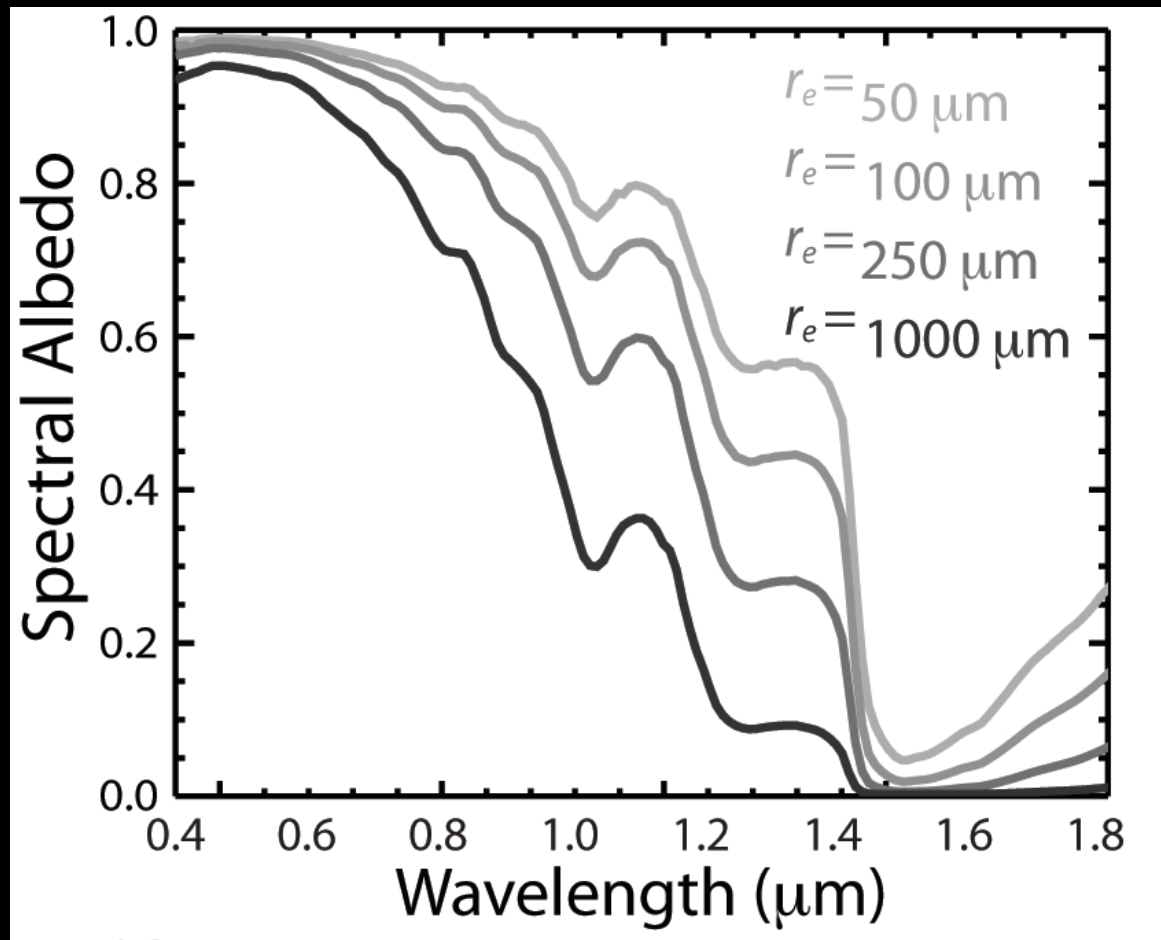
Spectral Mixing



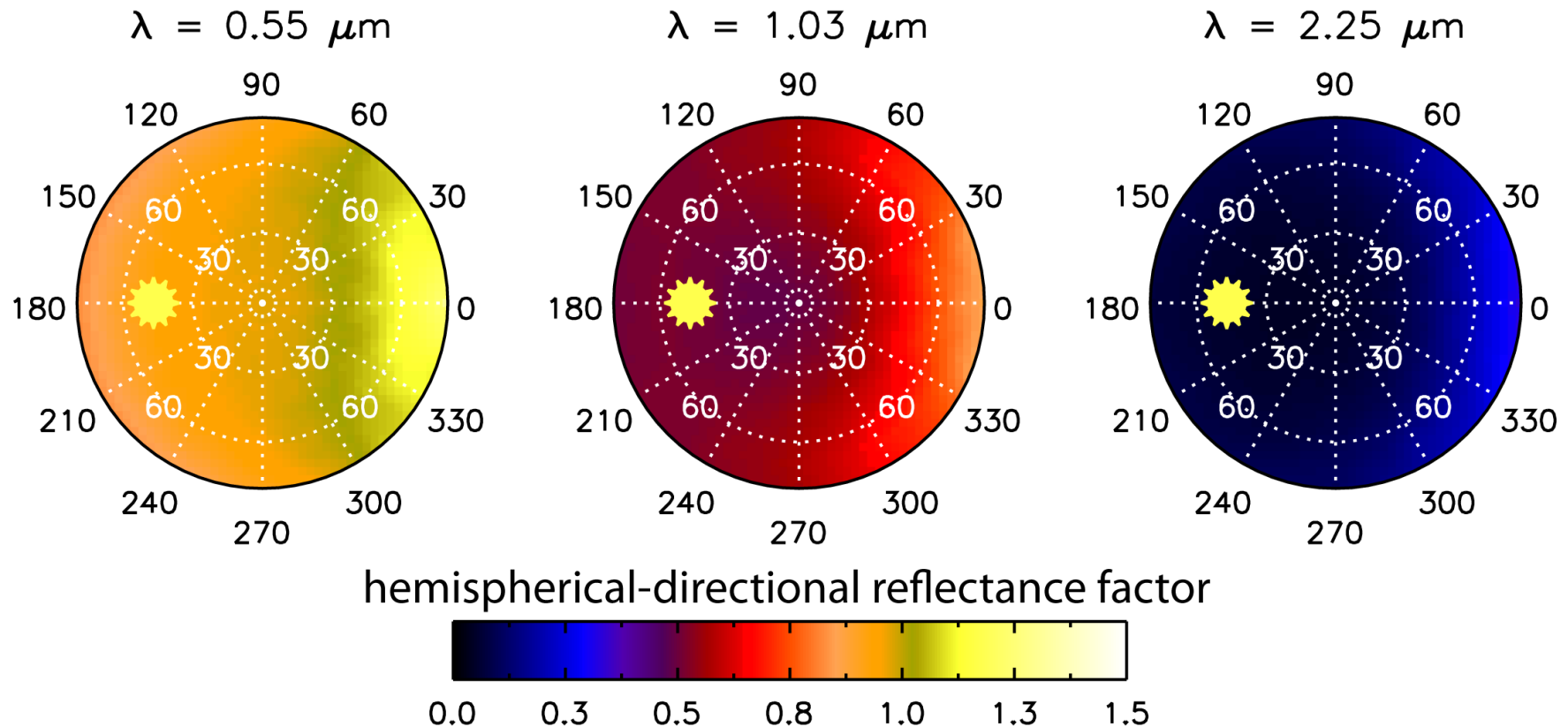
SNOW REFLECTANCE



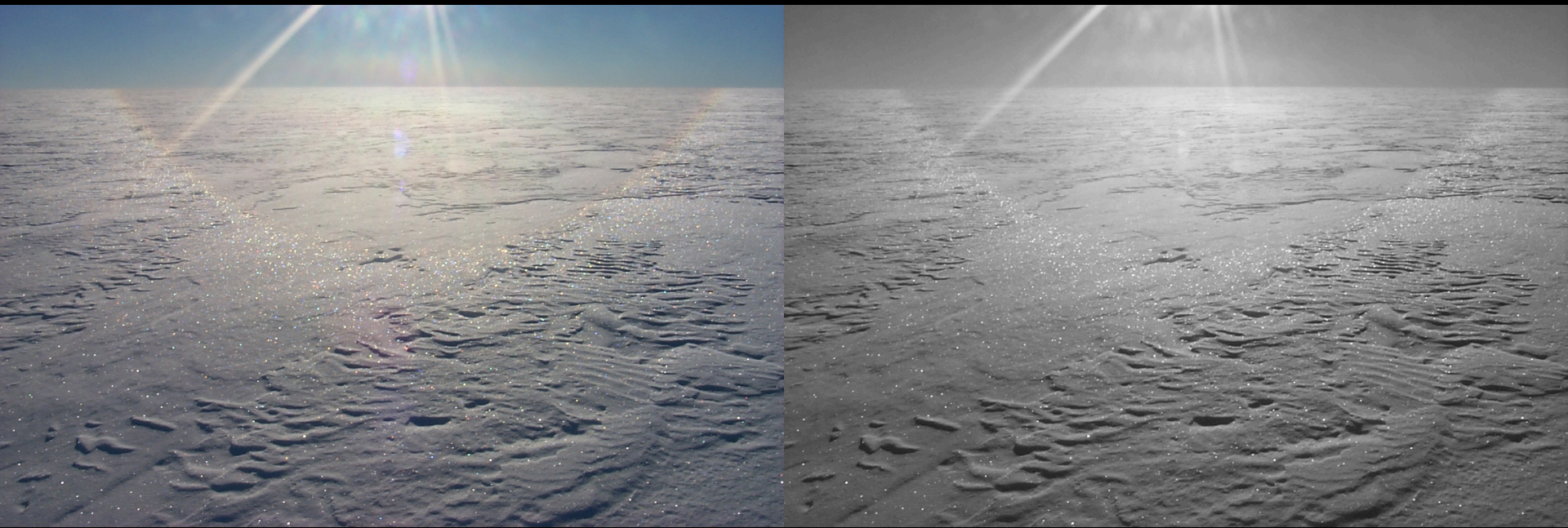
Snow Spectral Albedo



Snow Directional Reflectance – that is, what a satellite sees from different angles



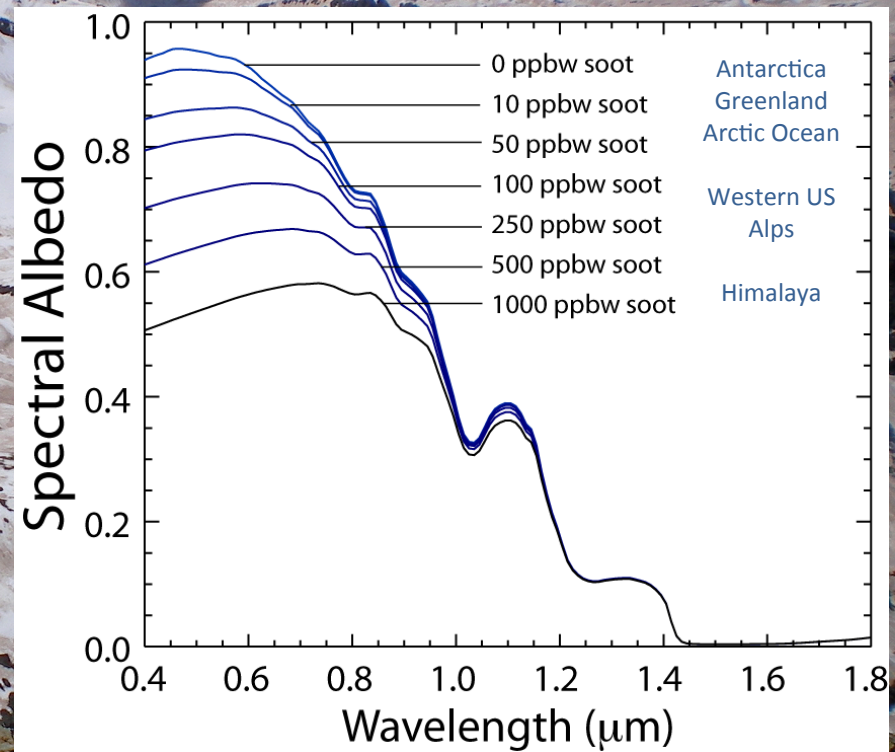
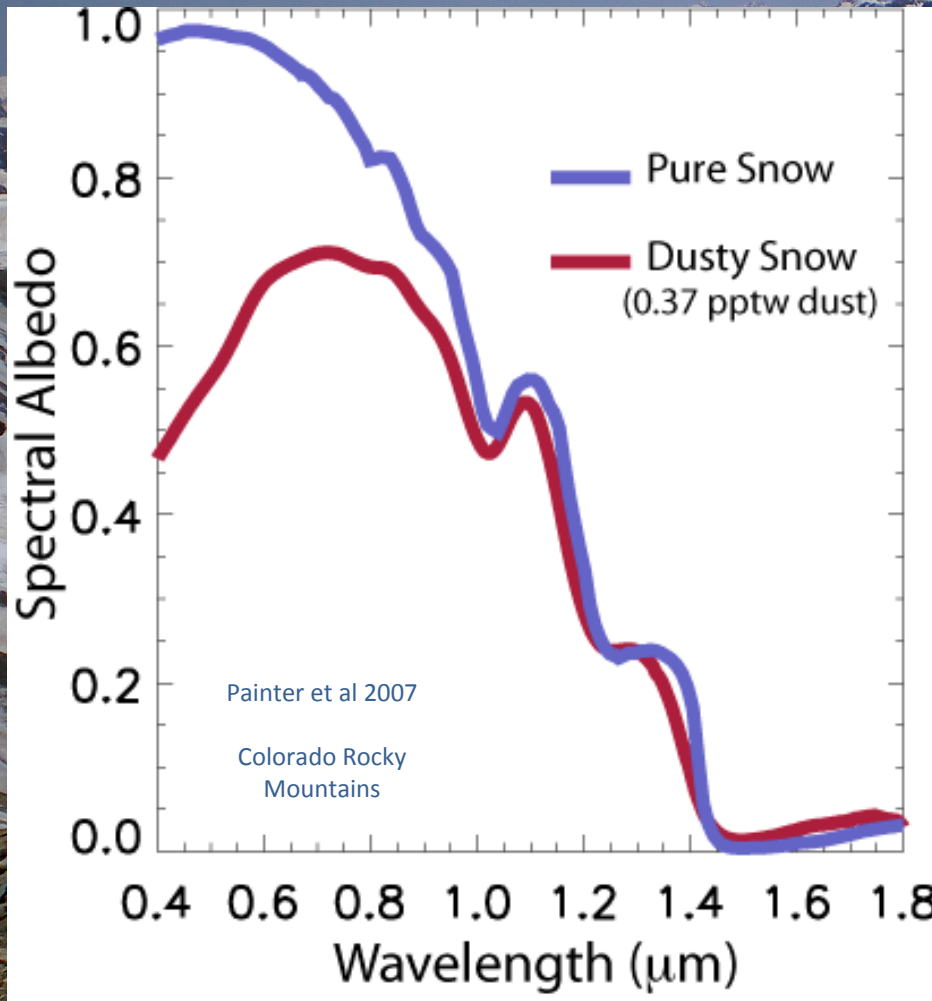
Snow Directional Reflectance



Vegetation Directional Reflectance



Effect of dust and black carbon on snow reflectance



Next Week

- The MODIS Snow Covered Area and Grain Size (MODSCAG) model and products
- The mixture of snow directional reflectances with vegetation and soil reflectances
- The impacts of view geometry
- The improvements to hydrologic modeling and our understanding of climate change

